

APPENDIX F

REGULATED FLOOD FLOW-FREQUENCY ANALYSIS FOR THE SACRAMENTO/SAN JOAQUIN RIVER BASINS AND DELTA TRIBUTARIES



**US Army Corps
of Engineers**

Sacramento District

Post-Flood Assessment for 1983, 1986, 1995, and 1997
Central Valley, California

APPENDIX F

REGULATED FLOOD FLOW-FREQUENCY ANALYSIS FOR THE SACRAMENTO/SAN JOAQUIN RIVER BASINS AND DELTA TRIBUTARIES

REGULATED FLOOD FLOW-FREQUENCY CURVES

Regulated peak flood flow-frequency curves were developed at several selected locations within the Sacramento and San Joaquin River basins and the Tulare Lake Basin. The curves were developed to establish the relative frequency of annual peak flows at each location. Tables F-1 to F-3 include a list of the selected locations. Earlier curves developed at or near these locations were reevaluated and updated to incorporate recent floods including 1983, 1986, 1995, and 1997. The regulated peak flood flow-frequency curves at the identified locations are shown on Plates 1 to 33.

Due to the minimal amount of historical data, the regulated curves were only developed up to the 1 percent chance exceedence (100-year) event unless hypothetical events were developed. Recent Corps flow-frequency analyses and reservoir modeling, funded by FEMA, produced hypothetical events up to the 0.1% chance exceedence (1,000-year) event for several tributaries. The regulated hypothetical events were developed using balanced inflow hydrographs based on unregulated flow-frequency curves fitted to a distribution and derived from long-term historical records. The unregulated frequency curves used to develop the hypothetical events were based on computed probability.

Tables F-1, F-2, and F-3 also present the estimated exceedence interval (range in years) of each of the selected 1983, 1986, 1995, and 1997 floods at each location. For the locations downstream from where the Sacramento and San Joaquin rivers leave the foothills and flow into the broad floodplain, the exceedence intervals are based on the regulated peak flood flow-frequency estimates. These locations within the Sacramento River Basin are Vina Bridge, Butte City, Colusa, Wilkins Slough, and the latitudes of Verona and the City of Sacramento. The locations within the San Joaquin River Basin are El Nido, Newman, Maze Road Bridge, and Vernalis.

The exceedence intervals on the tributaries and the main stem gages at Keswick, Bend Bridge, Friant Dam and Gravelly Ford are based on unregulated flood frequency-volume-duration estimates for each flood. The flood frequency derived from unregulated volumes provides a more realistic estimate of the magnitude and expected exceedence of the flood at each location. Frequency estimates based on unregulated volumes can differ significantly from regulated estimates for several reasons.

- Low starting storage levels (significantly below the bottom of the flood pool) prior to a flood may result in much smaller releases below a major flood control reservoir than are expected for the magnitude of the event. Low starting storage levels in reservoirs upstream from major flood control reservoirs can also result in smaller flood releases.
- Typically, a flood control project's objective release can be expected to occur for a broad range of flood-frequencies. For example, the objective flow (5,000 cfs) for the Mokelumne River below Camanche Dam can be expected for flood exceedence intervals ranging from 8-50 years; see Plate 13. Using the unregulated frequency estimate helps to better define the range for the specific event during which the maximum release of 5,000 cfs was obtained.
- A storm's centering can also have a major impact on frequency estimates. For example, a storm may be centered upstream from a major flood control reservoir project and not over the intervening local contributing drainage between the project and the selected downstream location. The 1997 flood was the flood of record above Shasta Dam, but it was not the flood of record for the local tributaries between Keswick Dam and Bend Bridge. Using unregulated flood frequencies at Shasta Dam and Bend Bridge results in more consistent frequency estimates at both locations for the specific flood.
- On the lower reaches of the main stem of the Sacramento River, flows spread out across low-lying basins, over weirs, and through wide bypasses. This distribution of flow affects the computation of reliable estimates of unregulated flows. Also, locations along lower reaches of main stem rivers represent large drainage areas, often tens of thousands of square miles, where a high percentage of the area is unregulated. The contributing drainage area is generally too large for most major storms to be centered over the entire basin. In effect, several historical observed high flows of similar magnitude can result from different storms centered throughout the basin. For these reasons, the regulated curves should provide reasonable frequency estimates.

TABLE F-1
ESTIMATED EXCEEDENCE INTERVAL OF HISTORICAL FLOODS
IN THE SACRAMENTO VALLEY

Location	Plate No.	Historical Floods (Exceedence Interval, range in years)			
		Feb-Mar 83	Feb 86	Mar 95	Dec 96 -Jan 97
Sacramento River Basin					
Sacramento River at Keswick ¹	1	5-15	25-40	10-25	95-140
Sacramento River above Bend Bridge ¹	2	10-20	20-35	10-25	50-85
Sacramento River at Vina Bridge	3	50-80	5-10	5-10	5-20
Stony Creek below Black Butte Dam ¹	4	15-25	35-50	25-35	5-15
Sacramento River at Butte City	5	50-70	5-10	5-10	10-20
Sacramento River at Colusa	6	30-80	20-50	5-20	5-20
Sacramento River below Wilkins Slough	7	20-50	50-80	10-20	15-30
Feather River Basin					
Feather River at Oroville ¹	8	5-10	40-55	10-15	95-135
Feather River at Shanghai Bend ¹	9	5-10	40-55	10-15	85-130
Sacramento River at the Latitude of Verona	10	5-10	30-50	5-10	90-110
Sacramento R. at the Latitude of Sacramento	12	5-10	50-80	5-10	90-110
American River Basin					
American River at Fair Oaks ¹	11	3-5	55-65	5-10	50-60
Notes:					
1 Exceedence Interval of flood estimated from unregulated volume-duration flood flow-frequency relationships					

TABLE F-2
ESTIMATED EXCEEDENCE INTERVAL OF HISTORICAL FLOODS
IN THE SAN JOAQUIN RIVER BASIN

Location	Plate No.	Historical Floods (Exceedence Interval, range in years)			
		Feb-Mar 83	Feb 86	Mar 95	Dec 96 -Jan 97
San Joaquin River Basin					
San Joaquin River below Friant Dam and at Gravelly Ford ¹	18-19	10-20	25-50	10-25	60-80
Fresno River below Hidden Dam ¹	20	10-20	15-30	15-30	25-45
Chowchilla River below Buchanan Dam ¹ Ash Slough below Chowchilla River ¹ Berenda Slough below Chowchilla River ¹	21-23	10-20	15-30	10-20	15-25
Eastside Bypass near El Nido	24	10-20	5-10	5-10	80-100
Merced River at New Exchequer Dam and at Cressy ¹	25-26	10-20	20-40	10-20	50-60
San Joaquin River at Newman	27	25-50	10-20	5-10	90-110
Tuolumne River at Don Pedro Dam and at Modesto ¹	28-29	15-25	30-40	5-15	80-110
San Joaquin River at Maze Road Bridge	30	15-25	10-20	5-10	80-110
Stanislaus River at New Melones Dam and at Orange Blossom Bridge ¹	31-32	5-10	30-50	10-15	50-70
San Joaquin River at Vernalis	33	30-50	15-25	5-10	80-110
Eastside Tributaries					
Mokelumne River below Camanche Dam ¹	13	3-6	30-40	3-10	55-65
Calaveras River below New Hogan Dam and Mormon Slough at Bellota ¹	14-15	5-10	55-75	3-7	5-15
Littlejohn Creek below Farmington Dam and at Farmington ¹	16-17	10-15	30-45	3-6	5-10
Notes:					
1 Exceedence Interval of flood estimated from unregulated volume-duration flood flow-frequency relationships					

TABLE F-3
ESTIMATED EXCEEDENCE INTERVAL OF HISTORICAL FLOODS
IN THE TULARE LAKE BASIN

Location	Historical Floods (Exceedence Interval, range in years)			
	Feb- Mar 83	Feb 86	Mar 95	Dec 96 -Jan 97
Kings River at Pine Flat Dam ¹	5-10	20-40	10-20	40-60
Kaweah River at Terminus Dam ¹	5-10	10-20	5-10	15-25
Tule River at Success Dam ¹	5-10	10-20	5-10	10-20
Kern River at Isabella Dam ¹	5-10	10-20	5-15	15-25
Notes: 1 Exceedence Interval of flood estimated from unregulated volume-duration flood flow-frequency relationships				

All regulated peak flood flow-frequency curves (Plates 1 to 33) reflect existing conditions except at identified locations affected by levee failures. At those locations, the impacts of the levee failures were removed. The curves were extended to the 100-year exceedence interval by routing hypothetical events. Historical peak flows were plotted using median plotting positions. An explanation of several selected curves, by location, is included in the following sections.

Sacramento River Basin

Sacramento River at Keswick. The historical peak flow record (1944-98) is the period after completion of Shasta and Keswick dams. The more frequent releases from 12,000 to 16,000 cfs reflect normal conservation or power releases, whereas the objective flood control release from Keswick Dam is 79,000 cfs.

Sacramento River Above Bend Bridge. The flows at Bend Bridge are regulated by Shasta, Keswick, and Whiskeytown dams. The maximum historical flows are predominantly a result of the uncontrolled local drainage (2,432 square miles). The major contributing tributaries are Cottonwood, Cow, and Battle creeks. During peak flow periods, releases from Keswick Dam are generally at or below 20,000 cfs. The objective flow at Bend Bridge is 100,000 cfs.

Sacramento River at Vina Bridge. The flows at Vina Bridge are regulated by Shasta, Keswick, and Whiskeytown dams. The maximum historical flows are predominantly a result of the uncontrolled local drainage (4,510 square miles). The major contributing tributaries between Bend Bridge and Vina Bridge are Mill, Deer, and Thomes creeks. During peak flow periods,

releases from Keswick Dam are generally at or below 20,000 cfs. The channel capacity at Vina Bridge is 84,000 cfs. The maximum recorded discharges for the main river do not include water bypassing the station on the left bank. The exceedence intervals listed in Table F-1 are based on the regulated flood flow-frequency (Plate 3). Estimates of exceedence intervals for unregulated conditions at Vina Bridge and downstream would be similar to those tabulated for the Sacramento River at Keswick and above Bend Bridge. Likewise, exceedence intervals based on regulated flood flow-frequency for the Sacramento River above Bend Bridge would be similar to the estimates tabulated for the Sacramento River at Vina Bridge. Vina Bridge is near where the Sacramento River leaves the foothills and flows into a broad floodplain.

Stony Creek Below Black Butte Dam. The historical record (1965-98) is the period after completion of Black Butte Dam. The objective flood control release from the dam is 15,000 cfs.

Sacramento River at Butte City. Flows in the Sacramento River at Butte City are confined by project levees on both sides of the river. The right (west) bank levee begins just below Ord Ferry and continues downstream to the Sacramento Delta. Fremont Weir, below Knights Landing, is the first flood control structure on the right bank to permit floodflows to leave the river. The left bank levees begin just upstream from Butte City. During floods, overbank flow into Butte Basin occurs upstream from the left (east) bank levee when flows exceed 90,000 cfs. The combined overbank flow and eastside tributary runoff then flows south on the east bank floodplain into Butte Basin and the Sutter Bypass before reentering the Sacramento and Feather rivers above Verona and the Fremont Weir. The Sacramento River's design channel capacity at Butte City is 160,000 cfs.

Sacramento River at Colusa. Flows are confined by project levees on both sides of the river. There are two relief structures upstream on the left bank between Butte City and Colusa. When discharge exceeds about 60,000 cfs, flow begins to spill over Moulton Weir, 25.1 miles upstream, into the Butte Basin. When discharge exceeds about 30,000 cfs, flow begins to spill over Colusa Weir, 2.5 miles upstream on the left bank, into the Butte Basin and the Sutter Bypass. Flows at Colusa do not include flows over Colusa and Moulton Weirs. The Sacramento River's design channel capacity at Colusa is 65,000 cfs.

Sacramento River Below Wilkins Slough. Flows are confined by project levees on both sides of the river. Above 23,000 cfs, flows begin to spill into the Sutter Bypass over the Tisdale Weir, 1 mile upstream on the left bank. Flows at Colusa do not include flows over the Tisdale Weir. The Sacramento River's design channel capacity at this location is 30,000 cfs.

Feather River at Oroville. Flows in the Feather River at Oroville are regulated by Oroville Dam; therefore, the historical record (1969-97) is the period after completion of the Oroville Project. The more frequent flows from 3,000 to 17,000 cfs are a result of normal conservation or power releases. The objective flood control release from Oroville Dam is 150,000 cfs.

Feather River at Shanghai Bend, Below Yuba River. The regulated curve reflects operation of Oroville and New Bullards Bar dams. The objective flow at Shanghai Bend is 300,000 cfs. During peak flow periods of major floods, a large percentage of the flows are

generated by 1,200 square miles of predominantly uncontrolled drainage upstream from Shanghai Bend and downstream from Oroville and New Bullards Bar dams.

Sacramento River at the Latitude of Verona. The maximum 1-day flows reflect the sum of flows in the Sacramento River, Feather River, and the Sutter Bypass at their confluence above Verona and the Fremont Weir. Winter floodflows from the Colusa Basin, prevented from entering the Sacramento River at Knights Landing, pass through the Knights Landing Ridge Cut and enter the Yolo Bypass below the Fremont Weir. Colusa Basin flows are included in the frequency curve flows for the latitude of Sacramento. The regulated curve at the latitude of Verona reflects actual and simulated upstream regulation minus the effects of historical levee breaks.

American River at Fair Oaks. The flows in the American River at Fair Oaks are entirely regulated by Folsom and Nimbus dams (period of record: 1955-98). The objective flow at Fair Oaks is 115,000 cfs. The more frequent flows from 2,500 to 5,000 cfs reflect normal conservation or power releases. The maximum power release at Folsom Dam is about 8,000 cfs. Folsom Dam operation during hypothetical events is in compliance with the water control diagram agreed upon by the Bureau of Reclamation and SAFCA (initiated in 1994). The peak historical flow of 130,000 cfs occurred during the February 1986 flood.

Sacramento River at the Latitude of Sacramento. The maximum 1-day flows reflect the sum of flows of the Sacramento River at Sacramento, the Yolo Bypass at Woodland, and the American River. The Yolo Bypass at Woodland includes flow spills from the Fremont Weir and flows from the Colusa Basin and Cache Creek. The regulated curve at the latitude of Sacramento reflects actual and simulated upstream regulation minus the effects of historical levee breaks.

Eastside Tributaries to the Delta

Mokelumne River Below Camanche Dam. The historical record (1965-97) is the period after completion of the Camanche Project. The objective flood release is 5,000 cfs. The more frequent flows from 1,500 to 2,000 cfs reflect normal conservation or power releases.

Calaveras River Below New Hogan Dam. The objective flood release from New Hogan Dam is 12,500 cfs. Since completion of New Hogan Dam, this release has not yet been achieved during the period of record (1962-98) .

Mormon Slough at Bellota. The flow at Bellota is regulated by New Hogan Dam. The maximum historical flows are predominantly a result of the uncontrolled local drainage (110 square miles). The objective flow in Mormon Slough at Bellota is 12,500 cfs.

As shown on Plate 15, the peak flow at Bellota exceeded 15,000 cfs during the February 1986 flood because a portion of the release from New Hogan Dam contributed to the peak flow at Bellota before releases could be reduced to minimum flow. Releases ranged from 6,000 cfs several hours before the peak at Bellota to 2,000 cfs during the peak. The travel time from the dam to Bellota is more than 3 hours. However, the flow above 12,500 cfs was only a very short

duration; therefore, no failures of the Mormon Slough Project were experienced. The following improvements made since 1986 should benefit flood control operation of New Hogan Dam and reduce the chance of exceeding 12,500 cfs in the future:

- Development of a real-time model of the river above Bellota
- Installation of a telemetered gage on Cosgrove Creek, a tributary just downstream from New Hogan Dam. The real-time flows at this location will provide a good indication of timing and magnitude of downstream local flows

Littlejohn Creek Below Farmington Dam and at Farmington. The flows at Farmington are regulated almost entirely by the Farmington Project. The project includes Farmington Dam, completed in 1951, and the Duck Creek Diversion Structure. The diversion structure diverts flow from Duck Creek into Littlejohn Creek, upstream from Farmington. The objective flow is 2,000 cfs both below Farmington Dam and at Farmington.

The frequency curve indicates several times when releases from Farmington Dam exceeded 2,000 cfs; however, peak regulated releases from the dam are not measured but are determined by gate ratings. The gate ratings, developed prior to dam construction, are theoretical. The releases made based on gate ratings may not reflect the actual release. Therefore, an indicated release greater than 2,000 cfs, based on the theoretical gate ratings, may have been made to maintain gaged flows near the objective flow of 2,000 cfs at Farmington, during periods when no contributing flows occurred from both the Duck Creek Diversion channel and the small intervening local drainage area below the dam.

San Joaquin River Basin

San Joaquin River at Friant Dam and at Gravelly Ford. The historical record (1949-97) includes the period after completion of Friant Dam. The objective flood control release from Friant Dam is 8,000 cfs. Flow in Cottonwood Creek and Little Dry Creek (including Big Dry Creek Reservoir releases) enters the San Joaquin River below Friant Dam and must be accounted for in the operation of Friant Dam. Under flood conditions, floodflows can also be diverted into the Friant-Kern and Madera canals when capacity is available and there is a place to release the floodflows. Floodflows in the Friant-Kern Canal may be carried to the Kern River and then through the Kern River Intertie to the California Aqueduct. Floodflows in the Madera Canal may be carried to the Fresno-Chowchilla River system.

The plotted hypothetical events were given more weight when fitting the graphical regulated flow-frequency curve to the more rare events. This is because the regulated hypothetical events are developed using balanced inflow hydrographs based on frequency curves fitted to a distribution and derived from long-term historical records. Accordingly, the plotted regulated hypothetical events are considered more statistically reliable than the plotted regulated historical events.

Fresno River Below Hidden Dam. The historical record (1976-98) is the period after completion of Hidden Dam. The objective flood control release from Hidden Dam is 5,000 cfs.

Chowchilla River Below Buchanan Dam, Ash Slough Below Chowchilla River, Berenda Slough Below Chowchilla River. The historical record (1976-98) is the period after completion of Buchanan Dam. The objective flood control release from Buchanan Dam is 7,000 cfs (5,000 cfs in Ash Slough and 2,000 cfs in Berenda Slough).

Eastside Bypass Near El Nido. Flows at this site are regulated by Buchanan, Hidden, Friant, and Pine Flat dams. The channel design flow is 16,500 cfs; however, flows of 21,000 cfs have been recorded without levee failures or overtopping. The maximum 1-day flow-frequency curve of simulated and recorded flows reflects in-channel flows only. The frequency curve does not reflect additional minor flows in the San Joaquin River.

Merced River at New Exchequer Dam and at Cressy. The historical record (1968-97) is the period after completion of New Exchequer Dam. The objective flood control release from New Exchequer Dam is 6,000 cfs. Flows in Dry Creek enter the Merced River above Cress and must be accounted for in the operation of New Exchequer Dam.

San Joaquin River at Newman. Flows at this site are regulated by additional reservoirs on the Merced River, Los Banos Creek, and Merced Streams. The channel design flow at this location is 45,000 cfs; however, levees begin to fail or are overtopped when flows exceed 40,000 cfs near Newman. The maximum 1-day flow-frequency curve of simulated and recorded flows reflects in-channel and out-of-bank flows along the latitude of the channel.

Tuolumne River at Don Pedro Dam and at Modesto. The historical record (1971-97) is the period after completion of the new Don Pedro Dam. The objective flood control release from Don Pedro Dam is 9,000 cfs. Flows in Dry Creek enter the Tuolumne River at Modesto and must be accounted for in the operation of Don Pedro Dam.

The plotted hypothetical events were given more weight when fitting the graphical regulated flow-frequency curve to the more rare events. This is because the regulated hypothetical events are developed using balanced inflow hydro graphs based on frequency curves fitted to a distribution and derived from long-term historical records. Accordingly, the plotted regulated hypothetical events are considered more statistically reliable than the plotted regulated historical events.

San Joaquin River at Maze Road Bridge. Flows at this site are regulated by additional reservoirs on the Tuolumne River. The channel design flow at this location is 46,000 cfs; however, levees begin to fail or are overtopped when flows exceed 40,000 cfs from Newman to Maze Road Bridge, except for one stretch. The San Joaquin River has limited channel capacity near the town of Grayson just upstream from the Tuolumne River. For periods of high flow at that location, Laird Slough carries most of the San Joaquin flow. The combined carrying capacity of San Joaquin River and Laird Slough is 26,000 cfs. The maximum 1-day flow-frequency curve of simulated and recorded flows reflects in-channel flows and out-of-bank flow

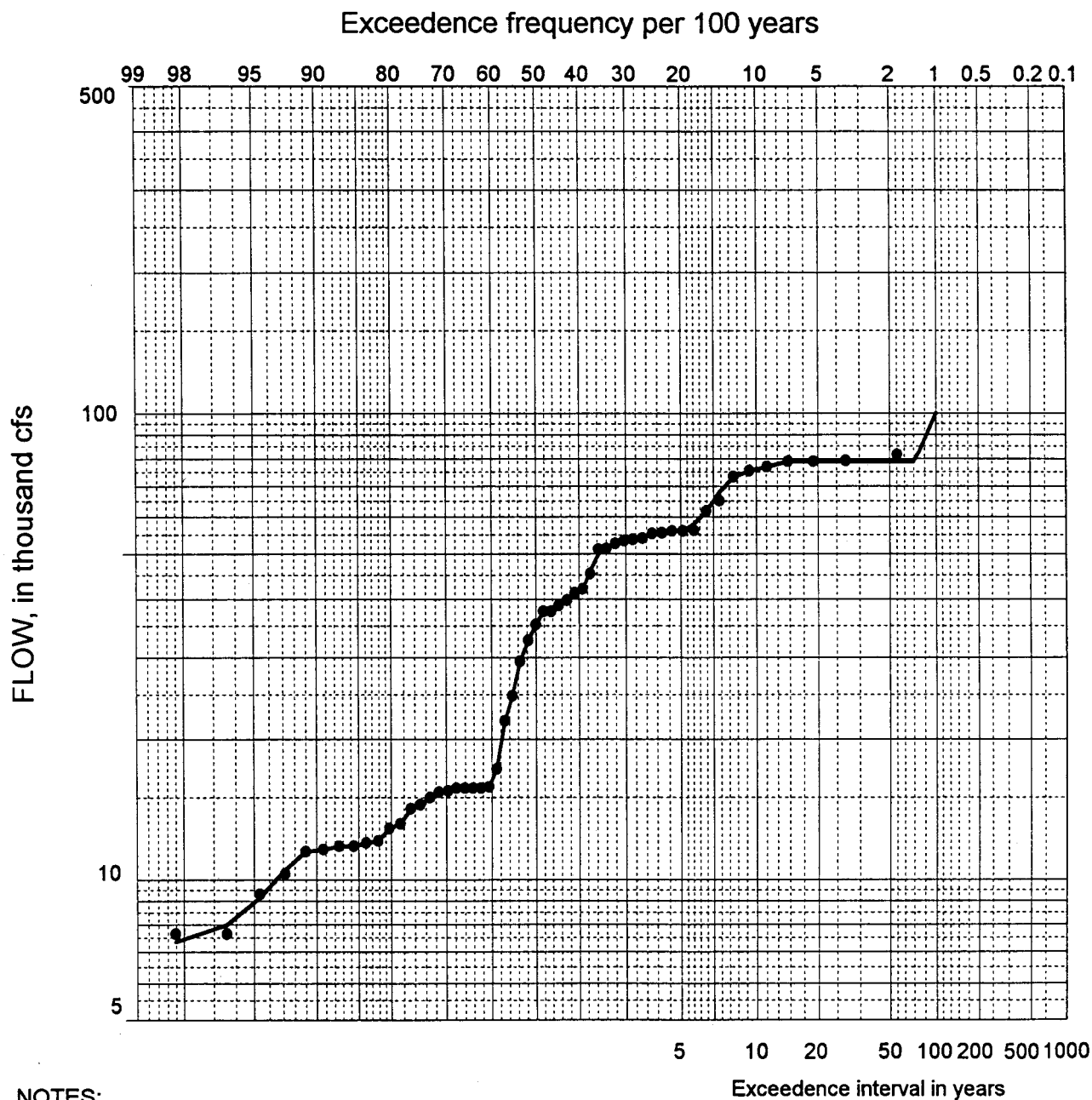
along the latitude of the channel. Out-of-channel flows may have occurred in 1938 (41,600 cfs) and did occur in 1969 (41,800 cfs), 1983 (38,400 cfs), and 1997 (59,300 cfs).

Stanislaus River at New Melones Dam and at Orange Blossom Bridge. The historical record (1978-97) is the period after completion of New Melones Dam and includes regulation by Tulloch Dam. Tulloch Dam impounds part of the runoff from the foothill drainage area below New Melones Dam. The objective flood control release from New Melones and Tulloch is 8,000 cfs.

San Joaquin River at Vernalis. Flows at this site are regulated by additional reservoirs on the Stanislaus River. The channel design flow at this location is 52,000 cfs; however, levees begin to fail or are overtopped when flows exceed 40,000 cfs near Vernalis. The maximum 1-day flow-frequency curve of simulated and recorded flows reflects in-channel flows and out-of-bank flow along the latitude of the channel. Out-of-channel flows occurred in 1938 (45,600 cfs), 1969 (34,800 cfs), 1983 (44,700 cfs), and 1997 (48,800 cfs).

Tulare Lake Basin

Table F-3 includes estimated exceedence intervals of historical flood events in the Tulare Lake Basin; however, revised frequency curves were not developed at these projects.



NOTES:

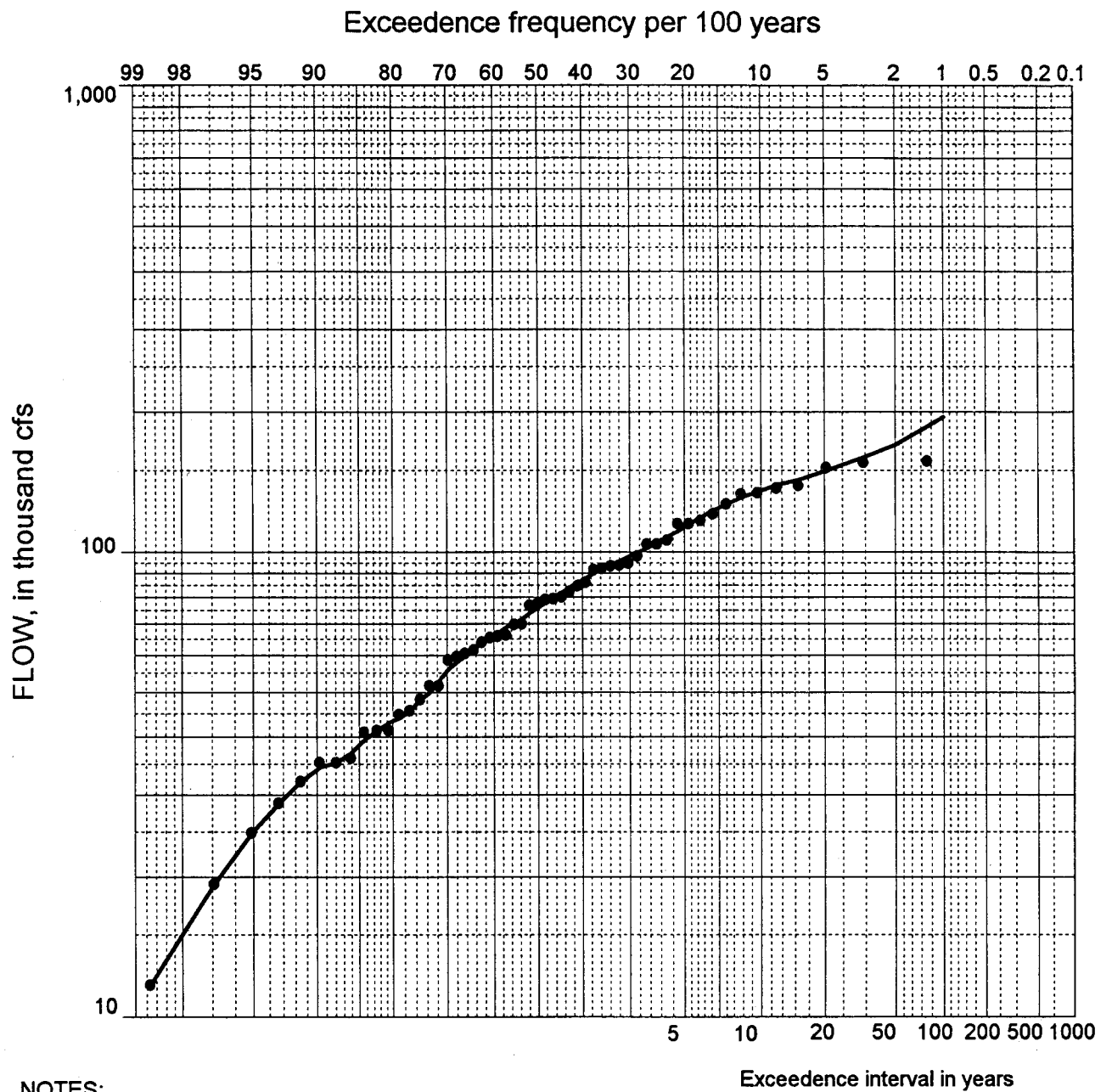
1. Drainage Area 6,468 sq. mi.
2. Median plotting positions.
3. Period of Record: 1944-1998

SACRAMENTO-SAN JOAQUIN BASIN COMPREHENSIVE STUDY
SACRAMENTO RIVER BASIN, CALIFORNIA

**PEAK RAIN FLOOD FREQUENCY CURVE
REGULATED CONDITION
SACRAMENTO RIVER AT KESWICK**

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by MVB



NOTES:

1. Drainage Area 8,900 sq. mi.
2. Median plotting positions.
3. Period of Record: 1944-1998

SACRAMENTO-SAN JOAQUIN BASIN COMPREHENSIVE STUDY
SACRAMENTO RIVER BASIN, CALIFORNIA

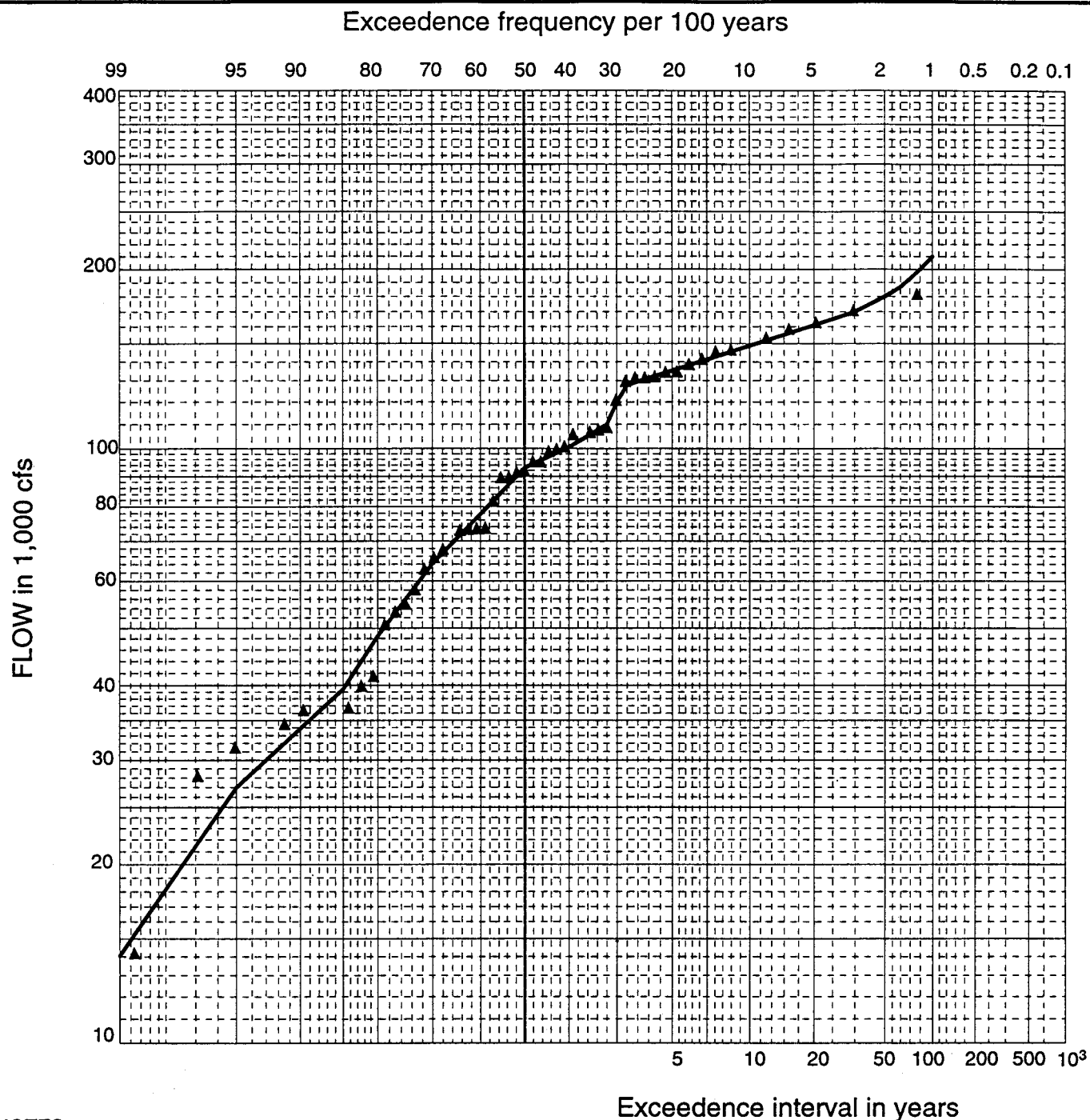
PEAK RAIN FLOOD FREQUENCY CURVE
REGULATED CONDITION
SACRAMENTO RIVER ABOVE BEND BRIDGE

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by MVB

Oct 98

PLATE 2



NOTES:

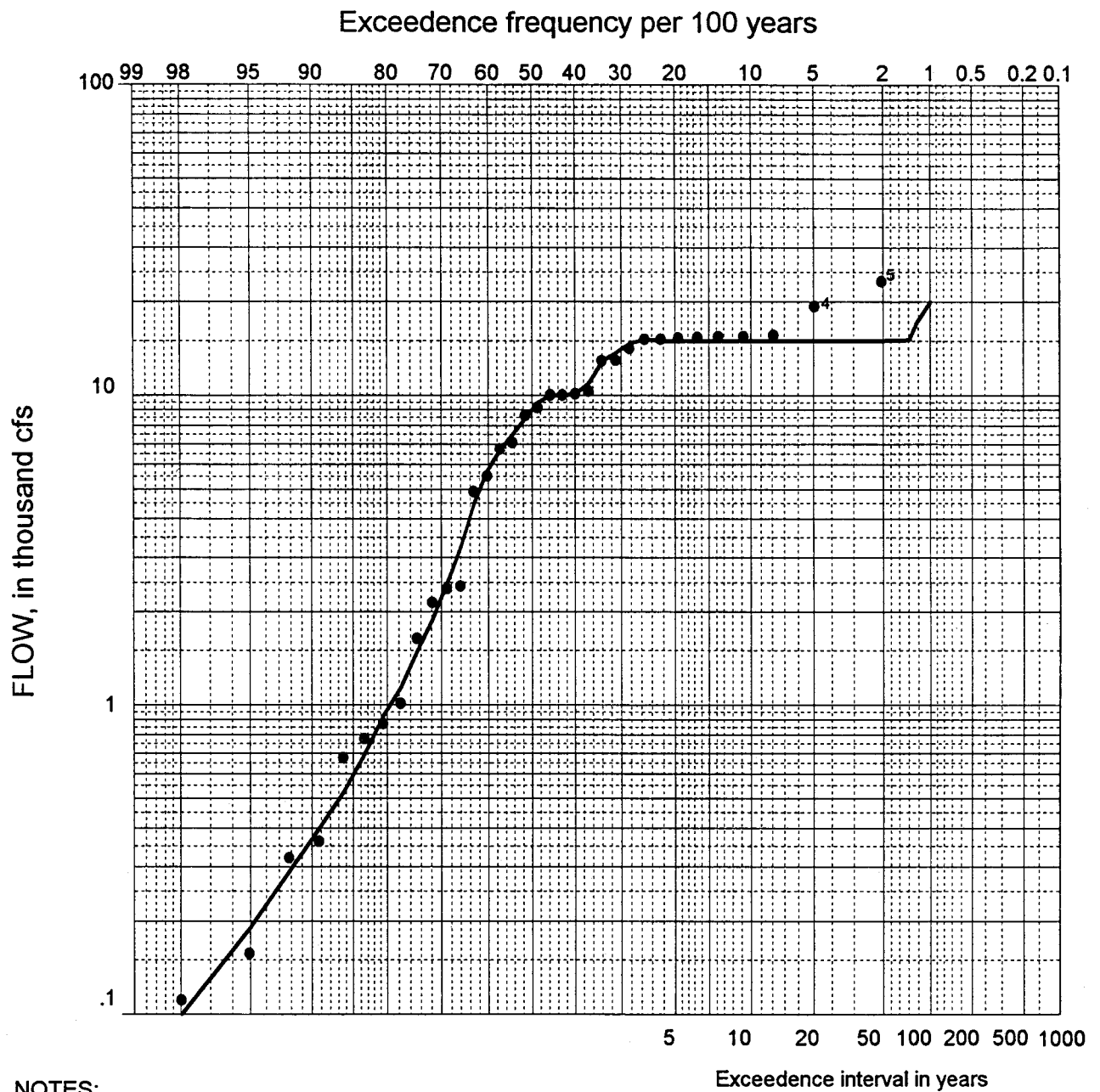
1. Curve is drawn graphically from recorded and simulated routings.
2. Drainage area 12,080 square miles.
3. During floods, overbank flow into Butte Basin occurs upstream from left bank levee. The combined overbank flow and tributary runoff then flows south on the east bank floodplain into Butte Sink and Sutter Bypass.
4. Curve does not include overbank flow to Butte Basin.
5. Curve was graphically extended to 100-yr event.
6. Median plotting positions, based on 55 years of record (1944-1998).

Prepared by RFC

**SACRAMENTO-SAN JOAQUIN BASIN COMPREHENSIVE STUDY
SACRAMENTO RIVER BASIN, CALIFORNIA**

**PEAK RAIN FLOOD FREQUENCY CURVE
REGULATED CONDITION
SACRAMENTO RIVER AT VINA BRIDGE**

**U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT**



NOTES:

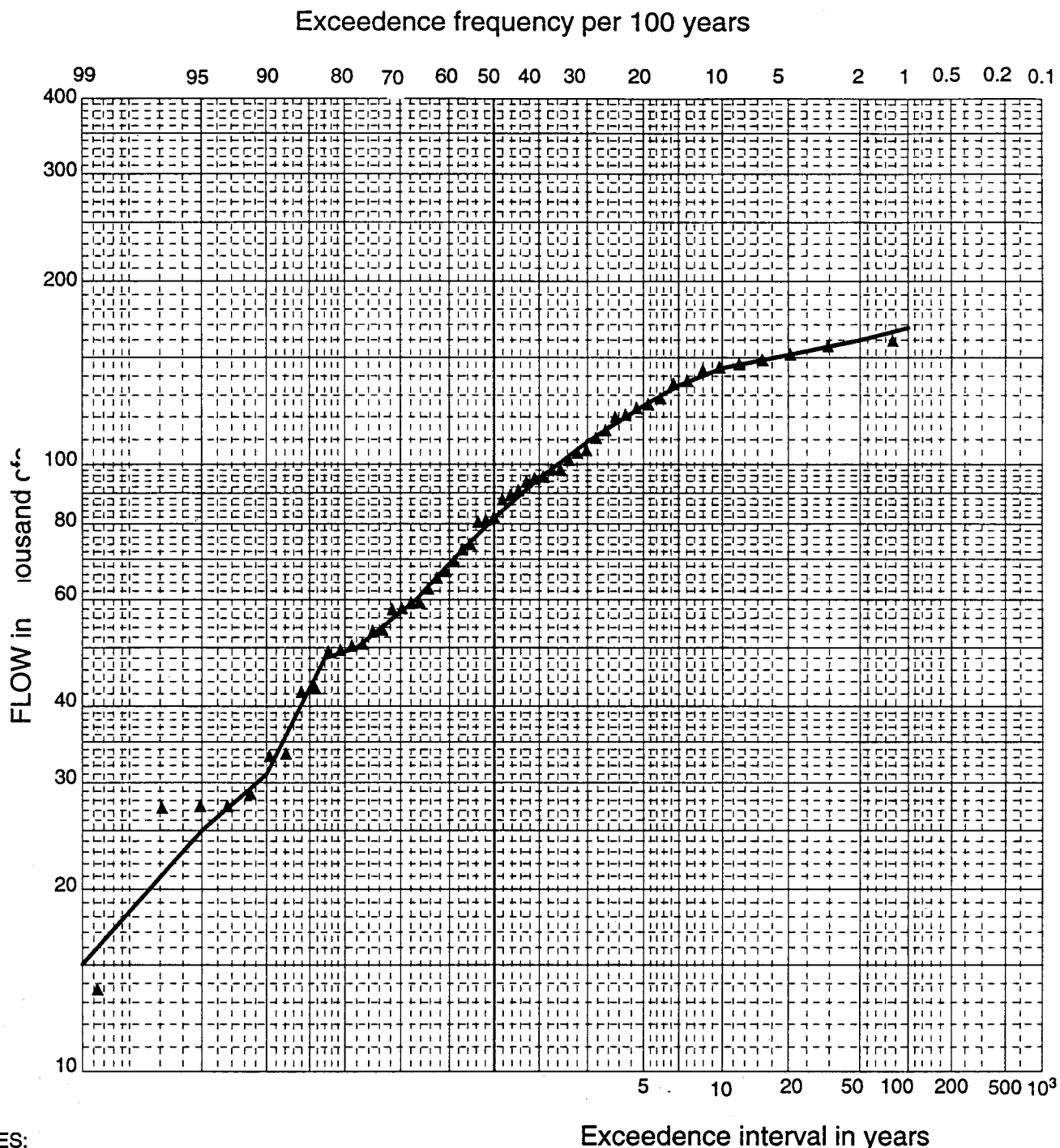
1. Drainage Area 740 sq. mi.
2. Median plotting positions.
3. Period of Record: 1965-1998
4. Release of 19,400 cfs occurred in first year of a flood operation (December 1964) and resulted from erroneous gate rating curve.
5. Release of 23,200 cfs occurred in February 1986 flood operation and resulted in attempts to limit flow over the spillway to reduce erosion to spillway chute.

**SACRAMENTO-SAN JOAQUIN BASIN COMPREHENSIVE STUDY
SACRAMENTO RIVER BASIN, CALIFORNIA**

**PEAK RAIN FLOOD FREQUENCY CURVE
REGULATED CONDITION
STONY CREEK BELOW BLACK BUTTE DAM**

**U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT**

Prepared by MVB



NOTES:

1. This curve drawn graphically from recorded data .
2. During floods, natural overbank flow into Butte Basin occurs upstream of the left bank levee. The combined overbank flow and flow from the eastside tributaries then flow south on the east bank floodplain into Butte Sink and Sutter Bypass.
3. This curve does not reflect overbank flows to Butte Basin.
4. Median plotting positions, based on 55 years of flow data (1944-1998).
5. This curve was graphically extended to the 100-year event.

**SACRAMENTO-SAN JOAQUIN BASIN COMPREHENSIVE STUDY
SACRAMENTO RIVER BASIN, CALIFORNIA**

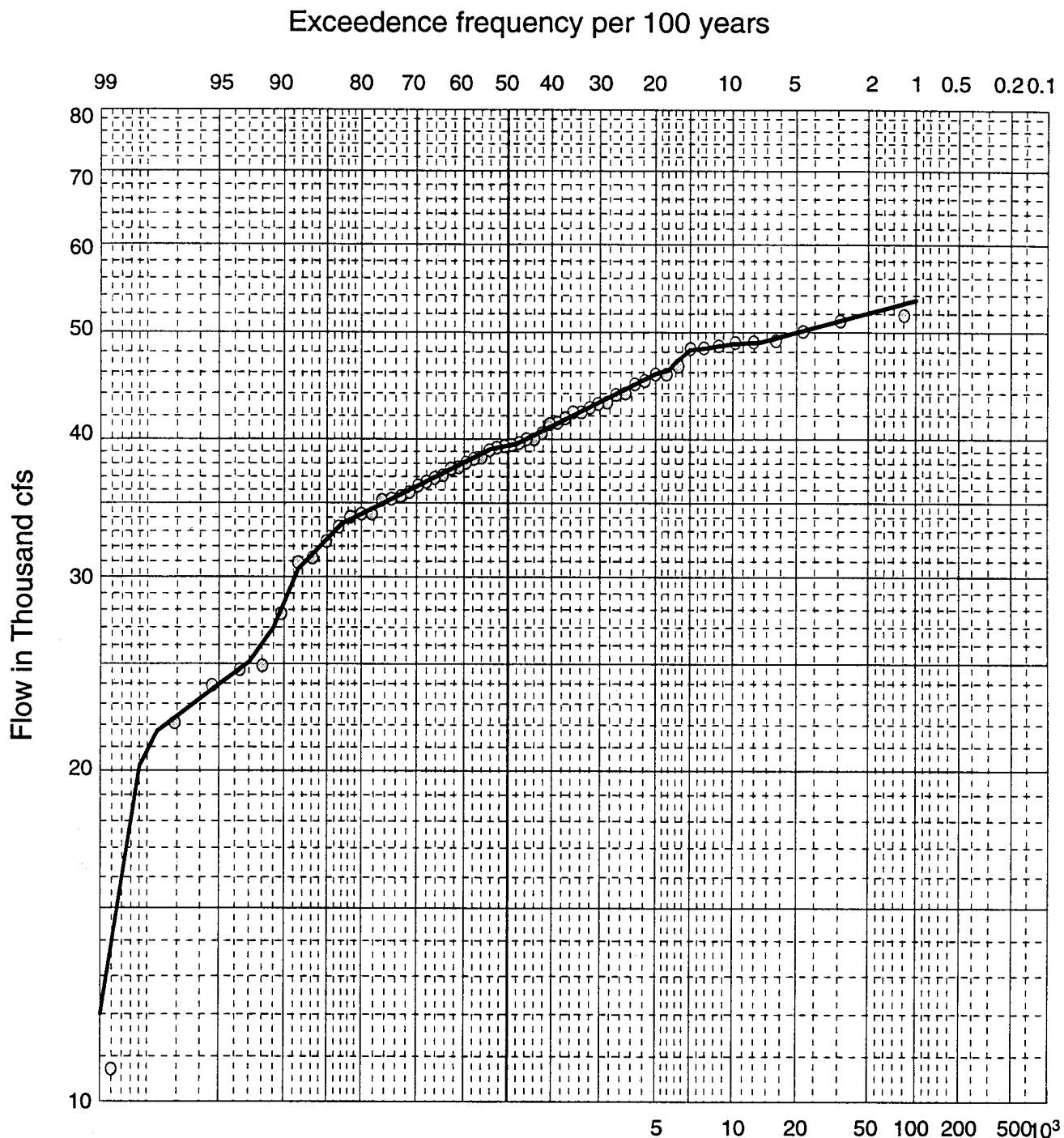
**PEAK RAIN FLOOD FREQUENCY CURVE
REGULATED CONDITION
SACRAMENTO RIVER AT BUTTE CITY**

**U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT**

Prepared by RFC

Nov. 1998

PLATE 5



NOTES:

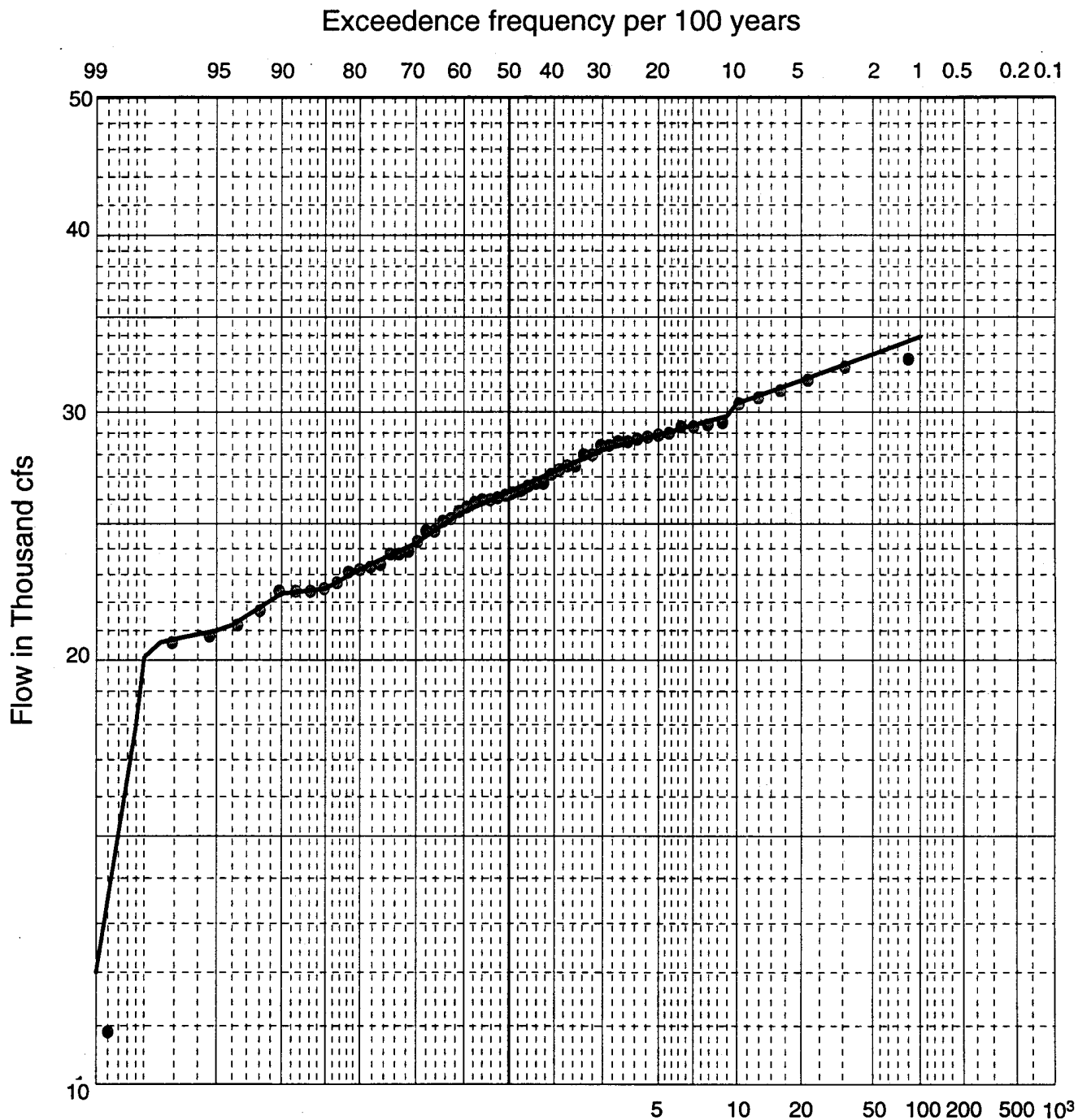
1. Curve drawn graphically from recorded data.
2. Drainage area is 12,090 square.miles.
3. Flows are confined by project levees on both sides of the river. Assume no levee failures up or downstream.
4. When discharge exceeds about 30,000 cfs, flow begins over Colusa Weir, 2.5 miles upstream on left bank, into Butte Sink and Sutter Bypass. Curve does not include flow over Colusa Weir.
5. Curve graphically extended to 100-yr event.
6. Median plotting positions, based on 58 years of record (1941-1998).

Exceedence interval in years

SACRAMENTO-SAN JOAQUIN BASIN COMPREHENSIVE STUDY
SACRAMENTO RIVER BASIN, CALIFORNIA

PEAK RAIN FLOOD FREQUENCY CURVE
REGULATED CONDITION
SACRAMENTO RIVER AT COLUSA

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT



NOTES:

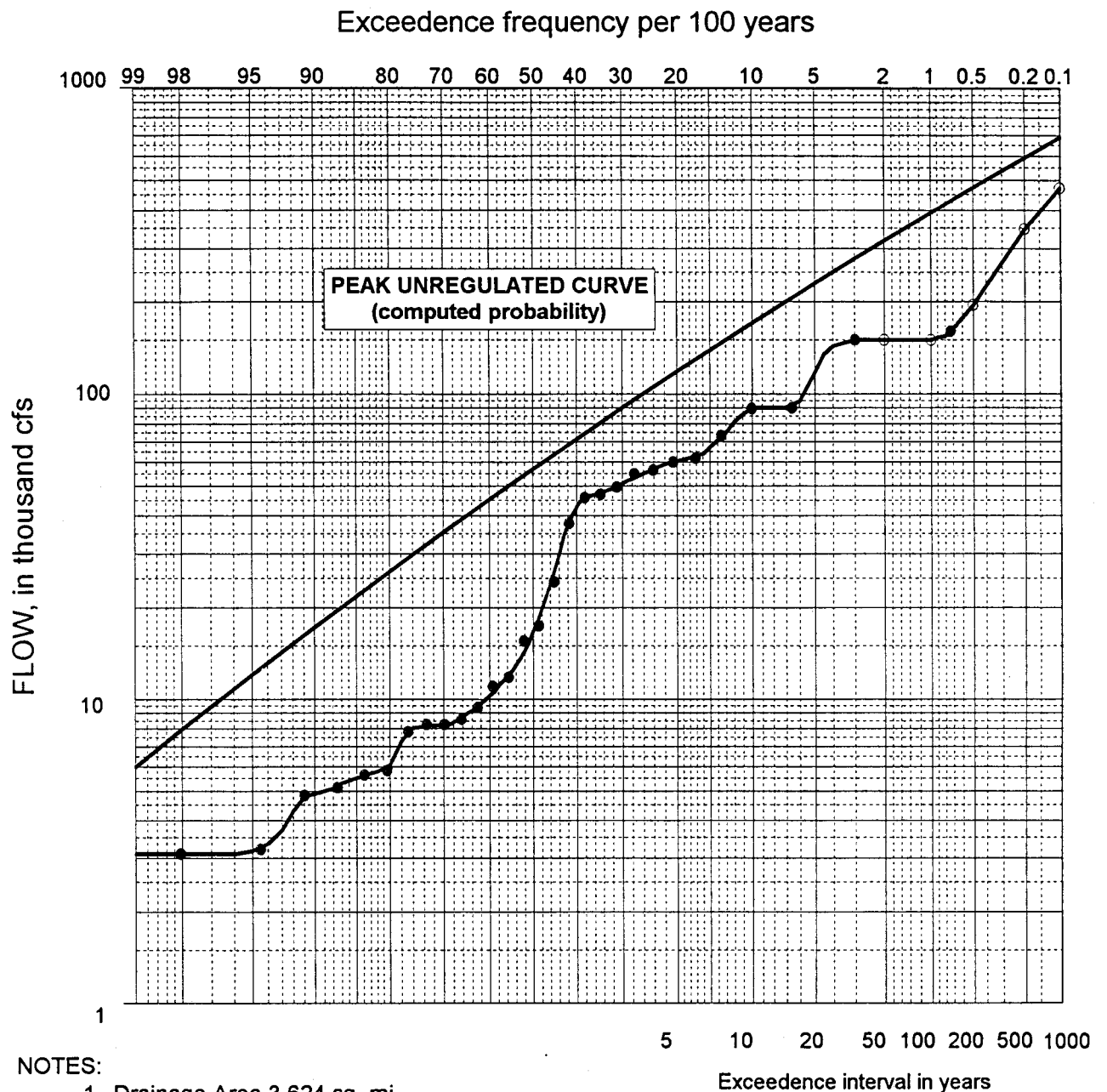
1. Curve drawn graphically from recorded data.
2. Drainage area is 12,926 square miles.
3. Flows are confined by project levees on both sides of the river. Assume no levee failures up or downstream.
4. When discharge exceeds 23,000 cfs, flow begins over Tisdale Weir, one mile upstream on the left bank, into Sutter Bypass. This curve does not include flow over Tisdale Weir.
5. Curve graphically extended to 100-yr event.
6. Median plotting positions, based on 58 years of record (1941-1998).

Exceedence interval in years

**SACRAMENTO-SAN JOAQUIN BASIN COMPREHENSIVE STUDY
SACRAMENTO RIVER BASIN, CALIFORNIA**

**PEAK RAIN FLOOD FREQUENCY CURVE
REGULATED CONDITION
SACRAMENTO R BLW WILKINS SLOUGH**

**U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT**



NOTES:

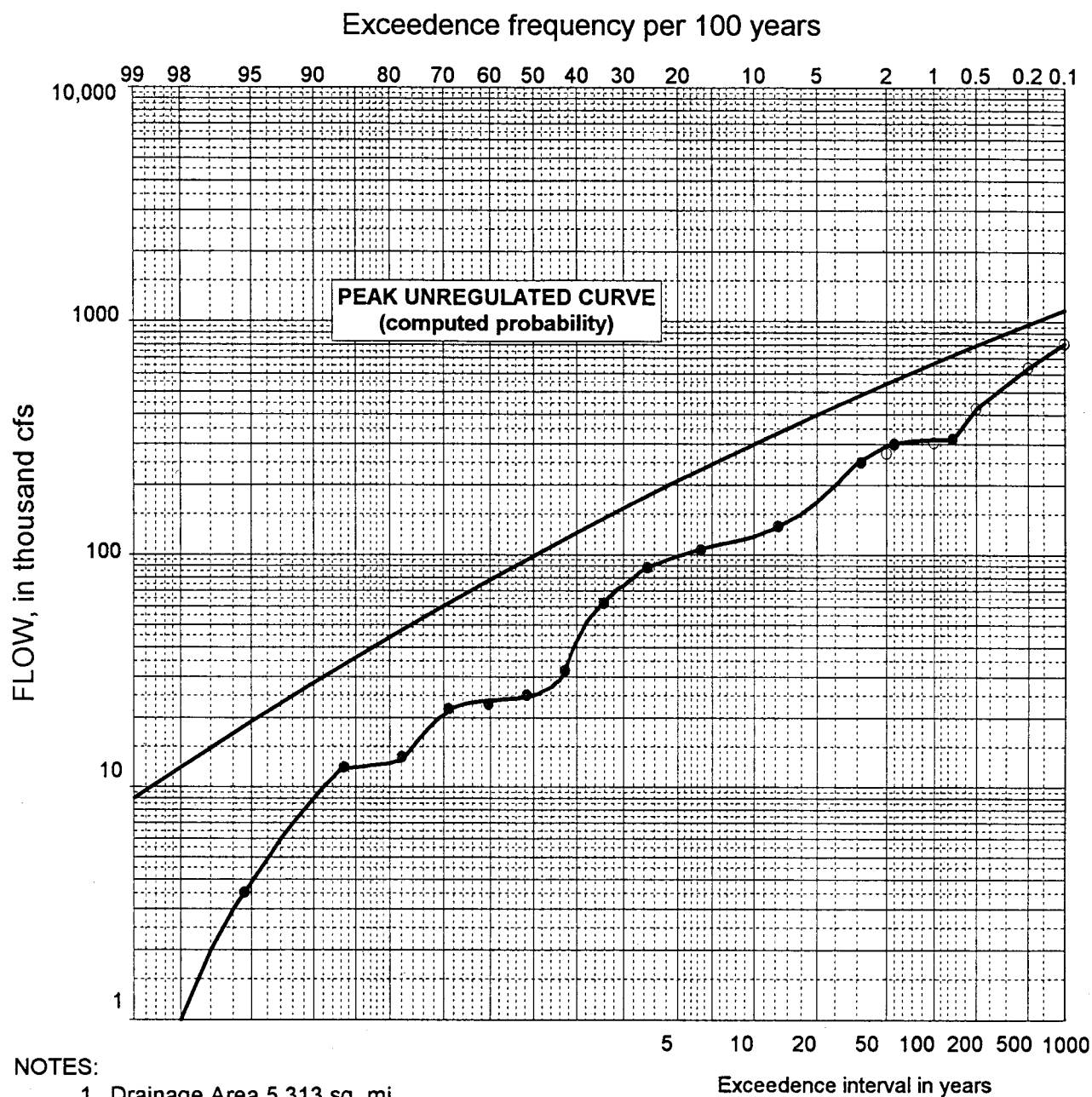
1. Drainage Area 3,624 sq. mi.
2. Median plotting positions
3. 29-year systematic record (1969 to 1997);
96-year historical period (1902-1997).
4. Historical maximum (1997).

SACRAMENTO-SAN JOAQUIN BASIN COMPREHENSIVE STUDY
SACRAMENTO RIVER BASIN, CALIFORNIA

**PEAK RAIN FLOOD FREQUENCY CURVE
REGULATED CONDITION
FEATHER RIVER AT OROVILLE**

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by RM



NOTES:

1. Drainage Area 5,313 sq. mi.
2. Median plotting positions.
3. 11-year systematic record (1970 to 1980);
94-year historical period (1904-1997).
4. Estimates of historical maximums
(1965, 1986, 1997).

SACRAMENTO-SAN JOAQUIN BASIN COMPREHENSIVE STUDY
SACRAMENTO RIVER BASIN, CALIFORNIA

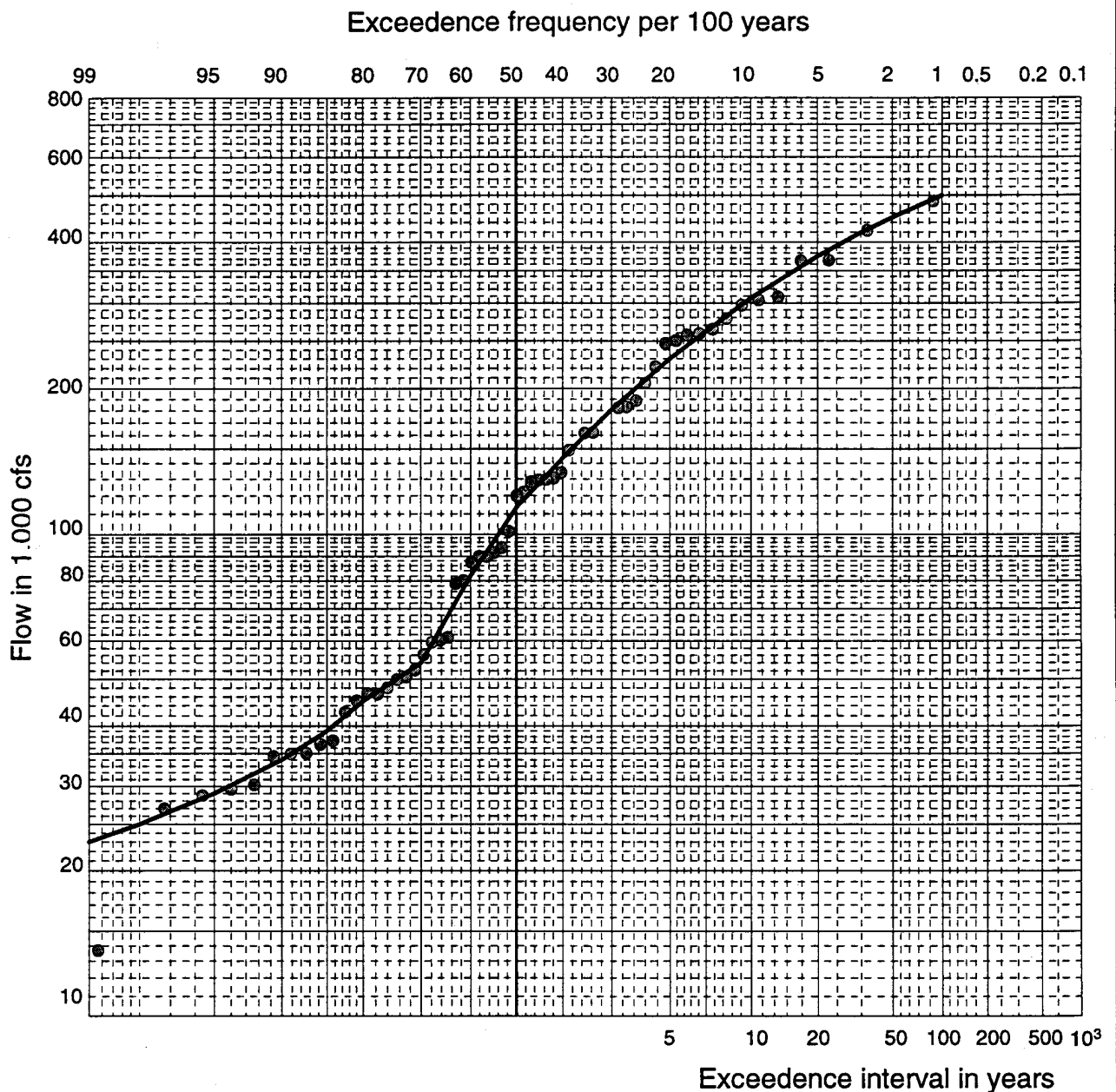
**PEAK RAIN FLOOD FREQUENCY CURVE
REGULATED CONDITION
FEATHER RIVER AT SHANGHAI BEND**

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by RM

Oct 98

PLATE 9



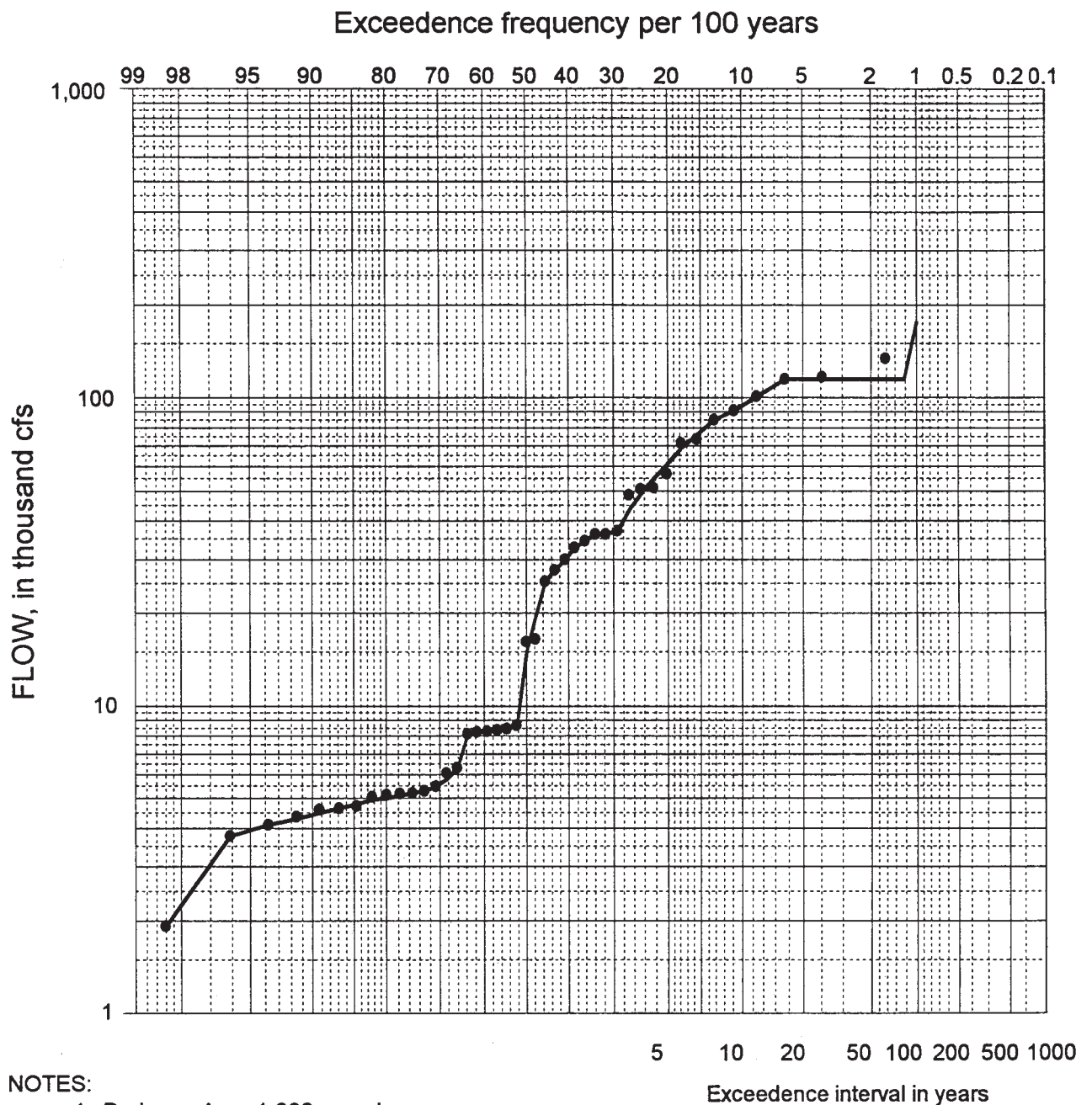
Notes:

1. Drainage Area is 21,251 square miles..
2. Curve is drawn graphically from recorded flows and flows from rerouted historical floods that reflect 1997 conditions.
3. Median plotting positions for 61 years of data (1937-1997).
4. Curves reflect the sum of flows of the Sacramento River, Feather River and Sutter Bypass at their confluence above Verona before they are split between Fremont Weir and the Sacramento River.

**SACRAMENTO-SAN JOAQUIN BASIN COMPREHENSIVE STUDY
SACRAMENTO RIVER BASIN, CALIFORNIA**

**1-DAY RAIN FLOOD FLOW FREQUENCY CURVE
REGULATED CONDITION
SACRAMENTO R AT THE LATITUDE OF VERONA**

**U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT**



NOTES:

1. Drainage Area 1,888 sq. mi.
2. Median plotting positions.
3. Period of Record: 1955-1998
4. Hypothetical operation is in compliance with the water control diagram agreed upon by the USBR and SAFCA (initiated in 1994).
5. The peak historical flow occurred during the February 1986 flood.

SACRAMENTO-SAN JOAQUIN BASIN COMPREHENSIVE STUDY
SACRAMENTO RIVER BASIN, CALIFORNIA

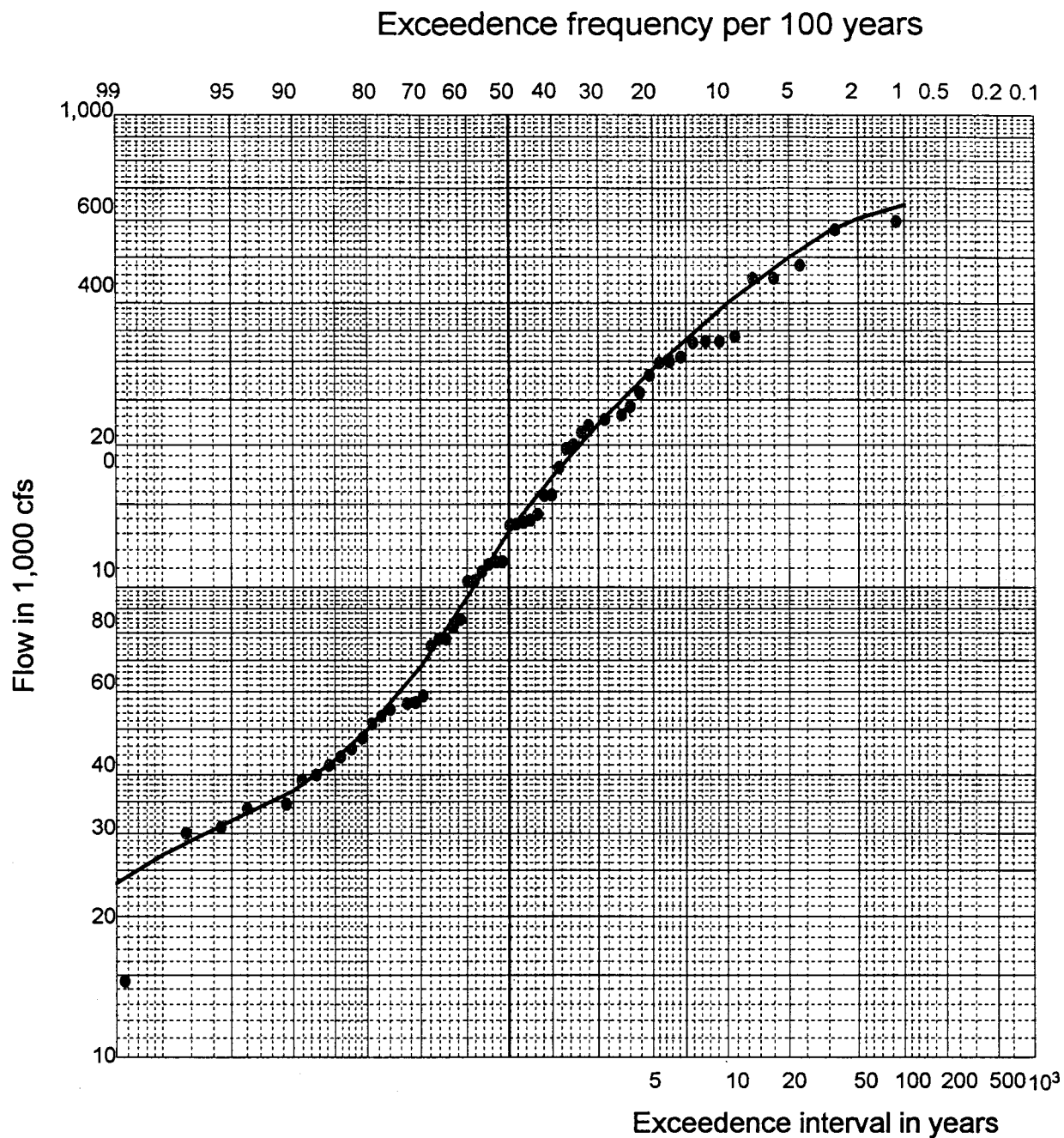
PEAK RAIN FLOOD FREQUENCY CURVE
REGULATED CONDITION
AMERICAN RIVER AT FAIR OAKS

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by RPY

Nov 98

PLATE 11



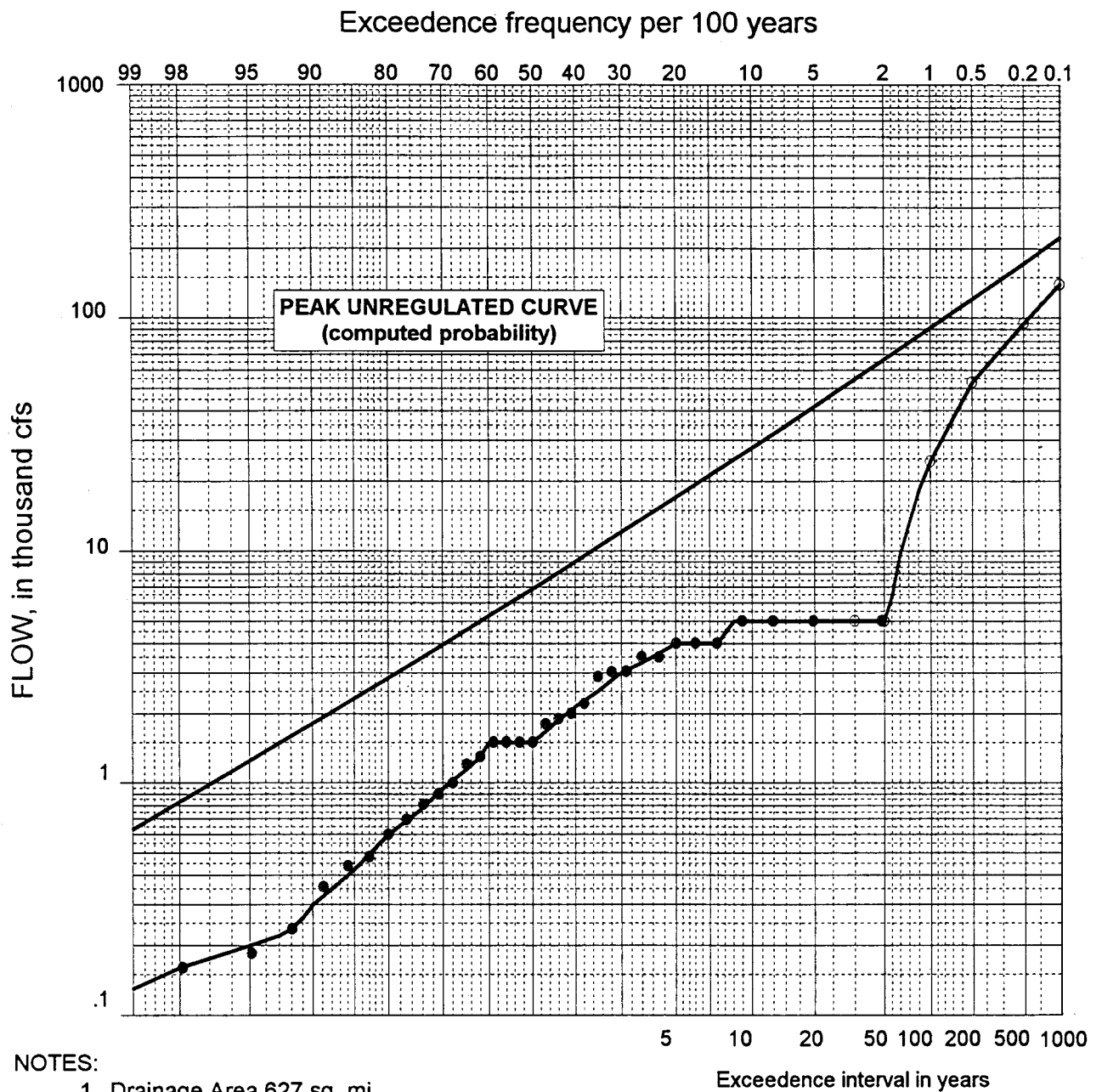
Notes:

1. Curve is drawn graphically from recorded flows and flows from rerouted historical floods that reflect 1997 conditions.
2. Median plotting positions for 61 years of data (1937-1997).
3. Curves reflect the sum of flows of the American River at Fair Oaks plus the Sacramento River, Feather River and Sutter Bypass at their confluence above Verona before they are split between Fremont Weir and the Sacramento River.

SACRAMENTO-SAN JOAQUIN BASIN COMPREHENSIVE STUDY
SACRAMENTO RIVER BASIN, CALIFORNIA

1-DAY RAIN FLOOD FLOW FREQUENCY CURVE
REGULATED CONDITION
SACRAMENTO R AT THE LATITUDE OF SACRAMENTO

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT



NOTES:

1. Drainage Area 627 sq. mi.
2. Median plotting positions
3. Period of Record: 1965-1997

SACRAMENTO-SAN JOAQUIN BASIN COMPREHENSIVE STUDY
SACRAMENTO RIVER BASIN, CALIFORNIA

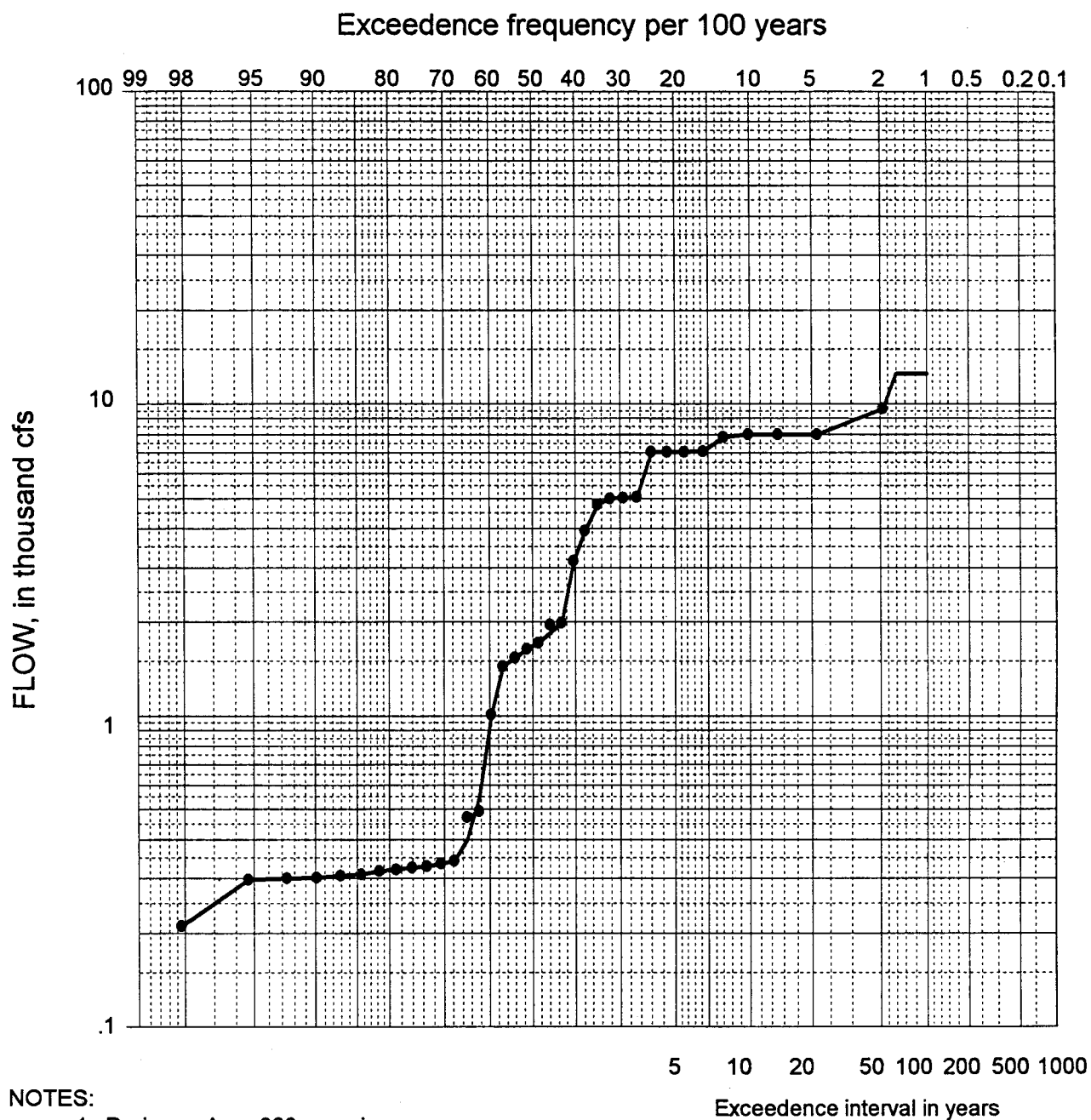
PEAK RAIN FLOOD FREQUENCY CURVE
REGULATED CONDITION
MOKELUMNE RIVER BELOW CAMANCHE DAM

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by RM

Oct 98

PLATE 13



NOTES:

1. Drainage Area 363 sq. mi.
2. Median plotting positions.
3. Period of Record: 1962-1998

SACRAMENTO-SAN JOAQUIN BASIN COMPREHENSIVE STUDY
SAN JOAQUIN RIVER BASIN, CALIFORNIA

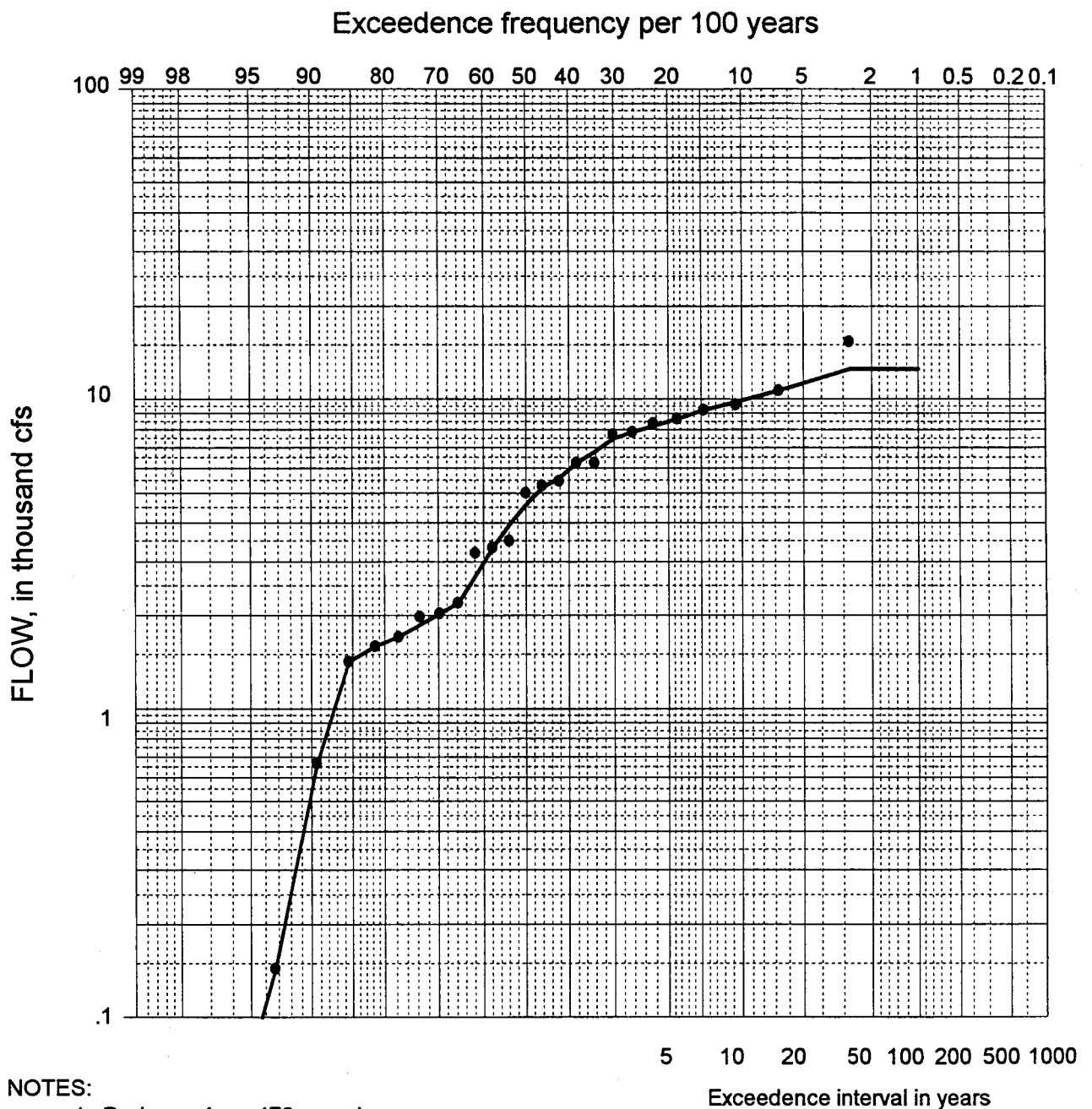
PEAK RAIN FLOOD FREQUENCY CURVE
REGULATED CONDITION
CALAVERAS RIVER BELOW NEW HOGAN DAM

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by RPY

Nov 98

PLATE 14



NOTES:

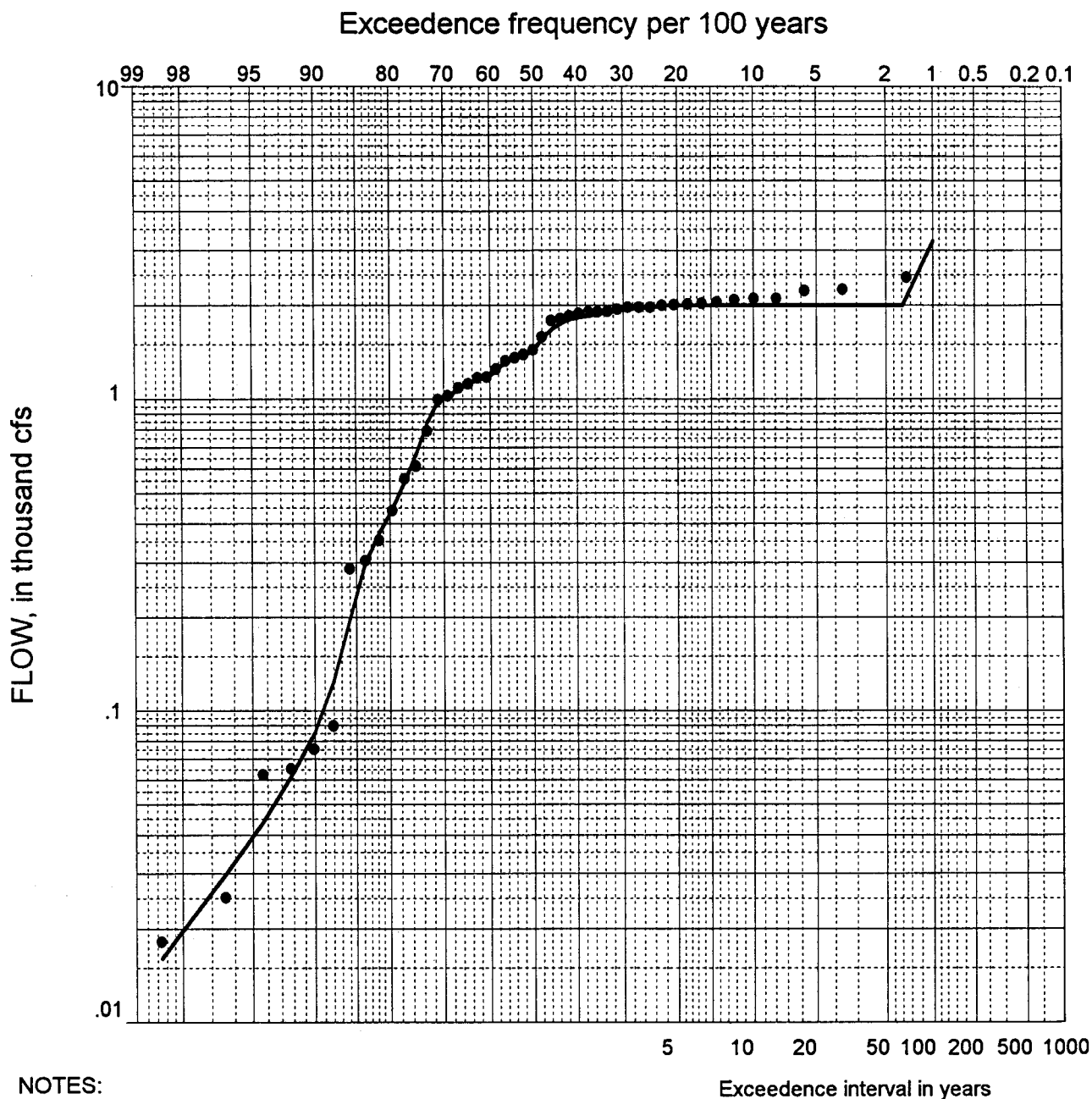
1. Drainage Area 470 sq. mi.
2. Median plotting positions.
3. Period of Record: 1962-1998
4. The peak historical flow occurred during the February 1986 flood and was a result of a combination of local flow and dam releases
5. Improvements since 1986 should benefit flood control operation of New Hogan Dam and reduce the chance of exceeding objective flows in the future.

SACRAMENTO-SAN JOAQUIN BASIN COMPREHENSIVE STUDY
SAN JOAQUIN RIVER BASIN, CALIFORNIA

**RAIN FLOOD FREQUENCY CURVE
REGULATED CONDITION
MORMON SLOUGH AT BELLOTA**

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by RPY



NOTES:

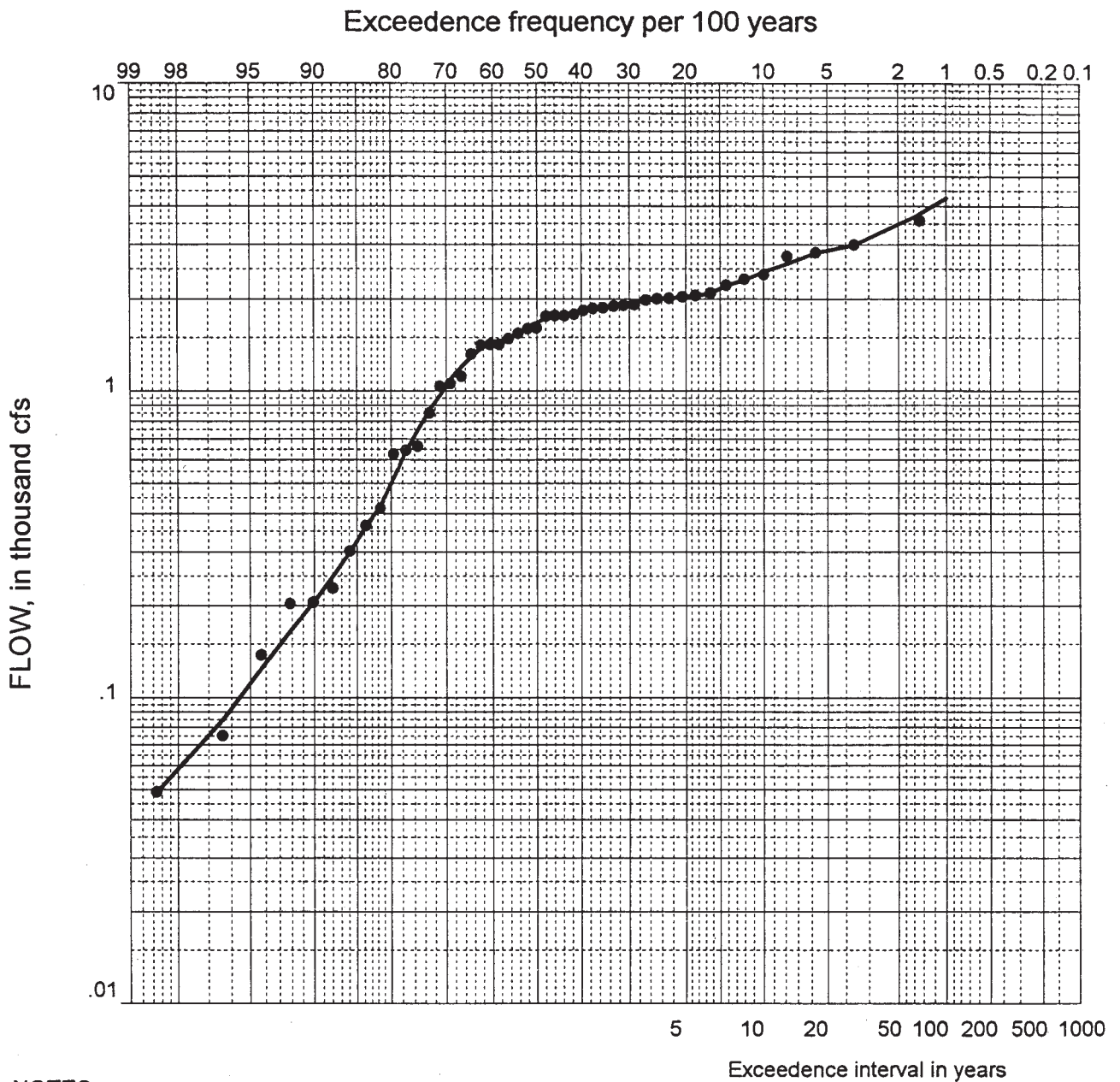
1. Drainage Area 212 sq. mi.
2. Median plotting positions.
3. Period of Record: 1952-1998
4. The peak historical outflows in descending order of magnitude are 1986, 1969 and 1965.
5. The peak historical outflows did not contribute to peak at the Town of Farmington. Peak outflow occurred when there was no flow in the Duck Creek Diversion channel and only minor local flow downstream of Farmington Dam.

SACRAMENTO-SAN JOAQUIN BASIN COMPREHENSIVE STUDY
SACRAMENTO RIVER BASIN, CALIFORNIA

**PEAK RAIN FLOOD FREQUENCY CURVE
UNREGULATED CONDITION
LITTLEJOHN CREEK BELOW FARMINGTON DAM**

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by MVB



NOTES:

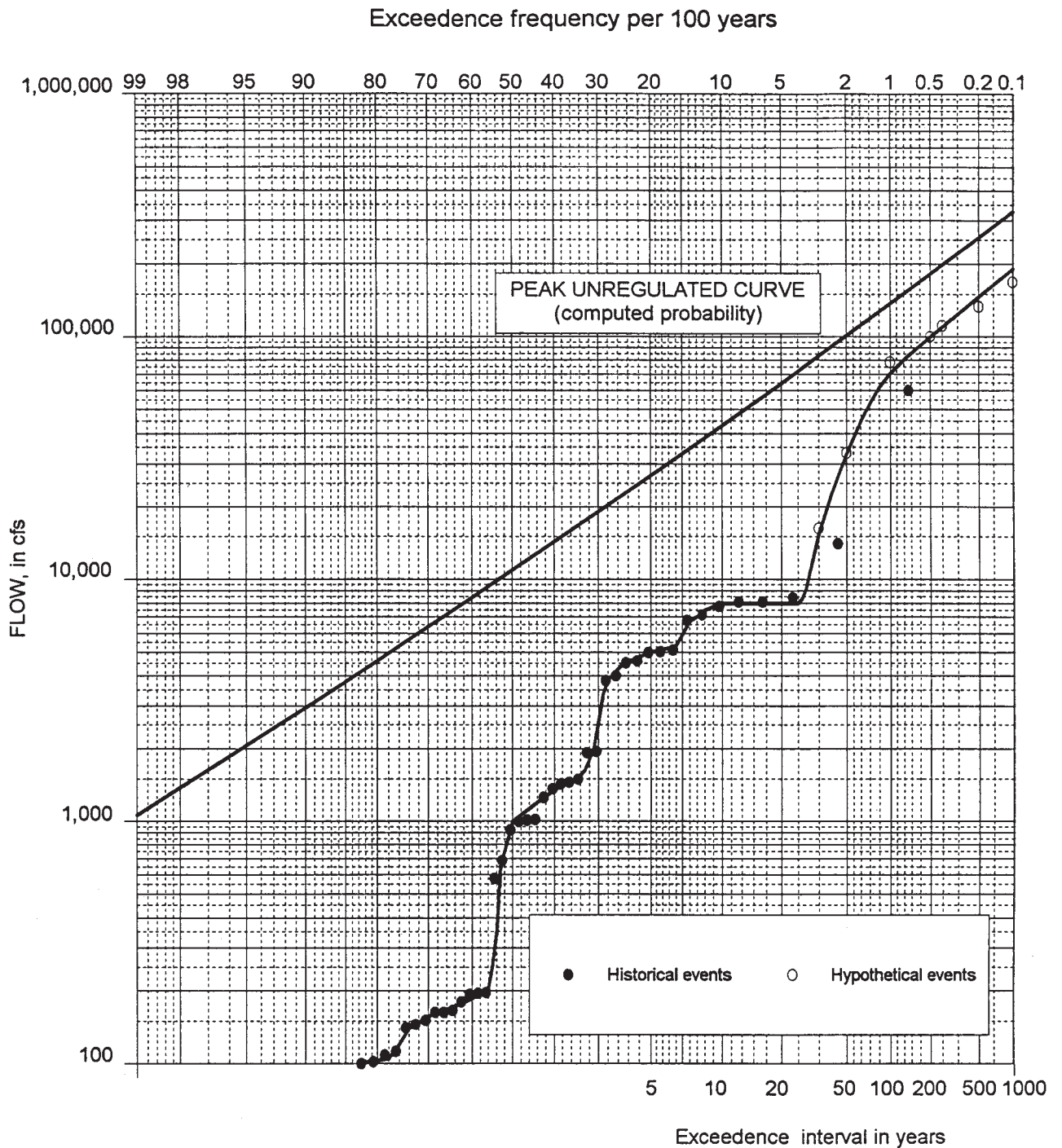
1. Drainage Area 247.9 sq. mi.
2. Median plotting positions.
3. Period of Record: 1952-1998
4. Duck Creek Diversion operation through 1966 does not reflect current operational criteria.
5. The four maximum historical peak flows in descending order of magnitude are 1958, 1986, 1983, and 1955. Farmington gates were closed during the peak flow period at the town of Farmington; therefore, the peaks were a result of diversions from Duck Creek and the local area below Farmington Dam.

Prepared by MVB

SACRAMENTO-SAN JOAQUIN BASIN COMPREHENSIVE STUDY
SACRAMENTO RIVER BASIN, CALIFORNIA

**PEAK RAIN FLOOD FREQUENCY CURVE
REGULATED CONDITION
LITTLEJOHN CREEK AT FARMINGTON**

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT



NOTES:

1. Median Plotting Positions
2. Drainage Area: 1,676 sq. mi.
3. 49 years of record (1949 to 1997)
4. 1997 event plotted as maximum in 94 years.

SACRAMENTO-SAN JOAQUIN BASIN COMPREHENSIVE STUDY

SAN JOAQUIN RIVER BASIN, CALIFORNIA

**PEAK RAIN FLOOD FREQUENCY CURVE
REGULATED CONDITION**

SAN JOAQUIN RIVER AT FRIANT DAM

U.S. ARMY CORPS OF ENGINEERS

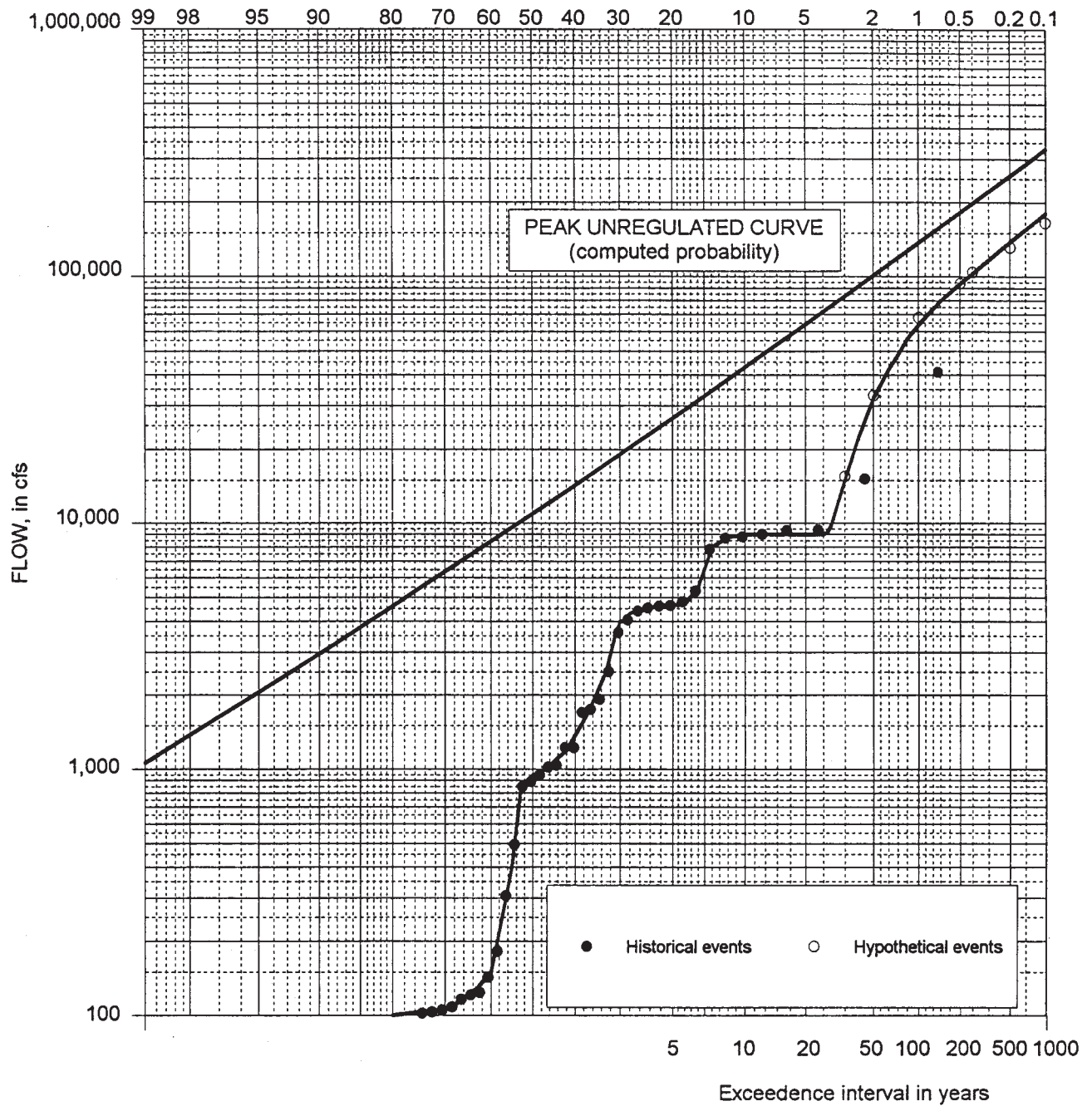
SACRAMENTO DISTRICT

Prepared by TKP

Nov 98

PLATE 18

Exceedence frequency per 100 years



NOTES:

1. Median Plotting Positions
2. Drainage Area: 1,805 sq. mi.
3. 49 years of record (1949 to 1997)
4. 1997 event plotted as maximum in 94 years.

SACRAMENTO-SAN JOAQUIN BASIN COMPREHENSIVE STUDY
SAN JOAQUIN RIVER BASIN, CALIFORNIA

PEAK RAIN FLOOD FREQUENCY CURVE
REGULATED CONDITION

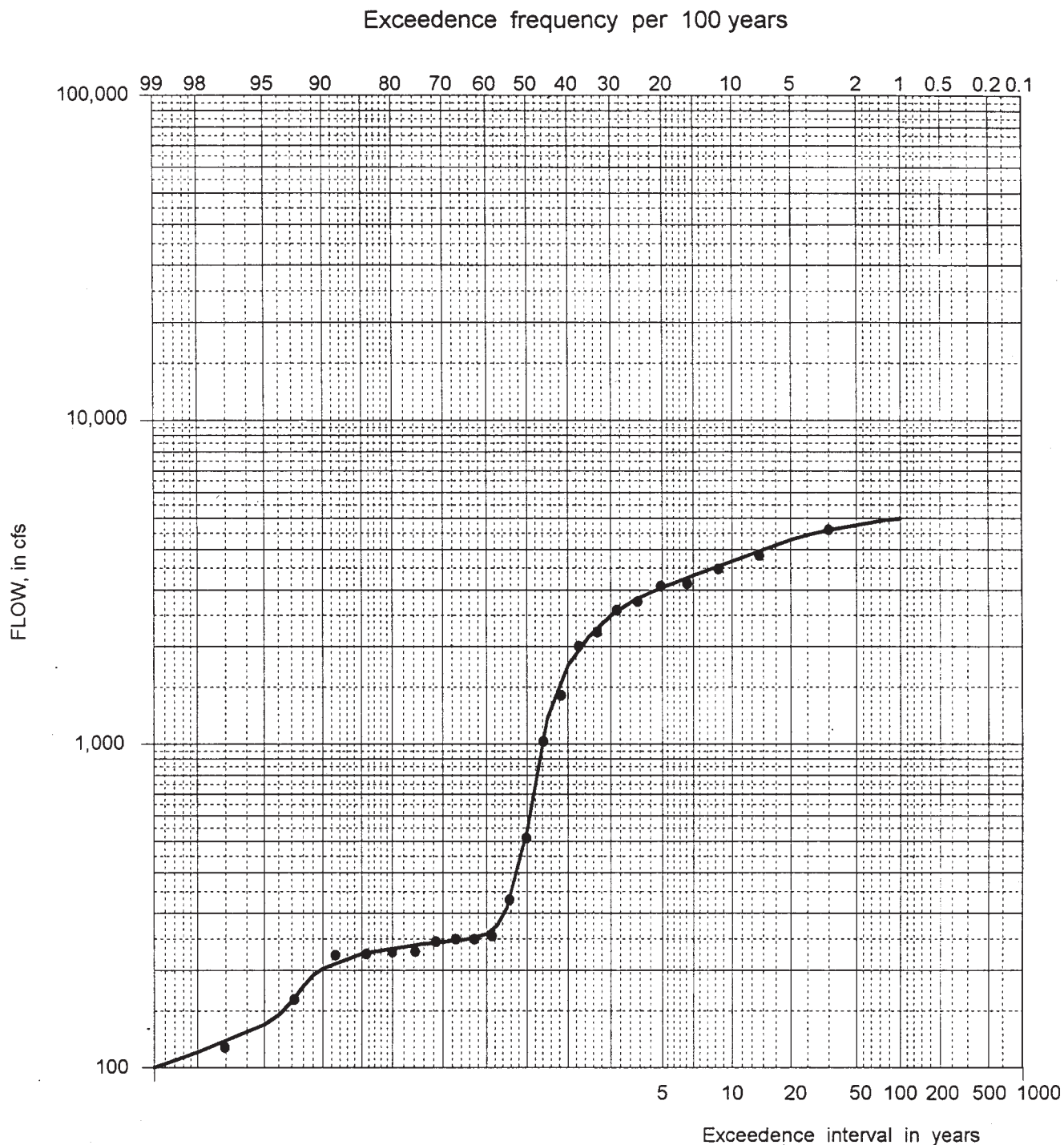
SAN JOAQUIN RIVER AT GRAVELLY FORD

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by TKP

Nov 98

PLATE 19



NOTES:

1. Median Plotting Positions
2. Drainage Area: 234 sq. mi.
3. 23 years of record (1976 to 1998)

**SACRAMENTO-SAN JOAQUIN BASIN COMPREHENSIVE STUDY
SAN JOAQUIN RIVER BASIN, CALIFORNIA**

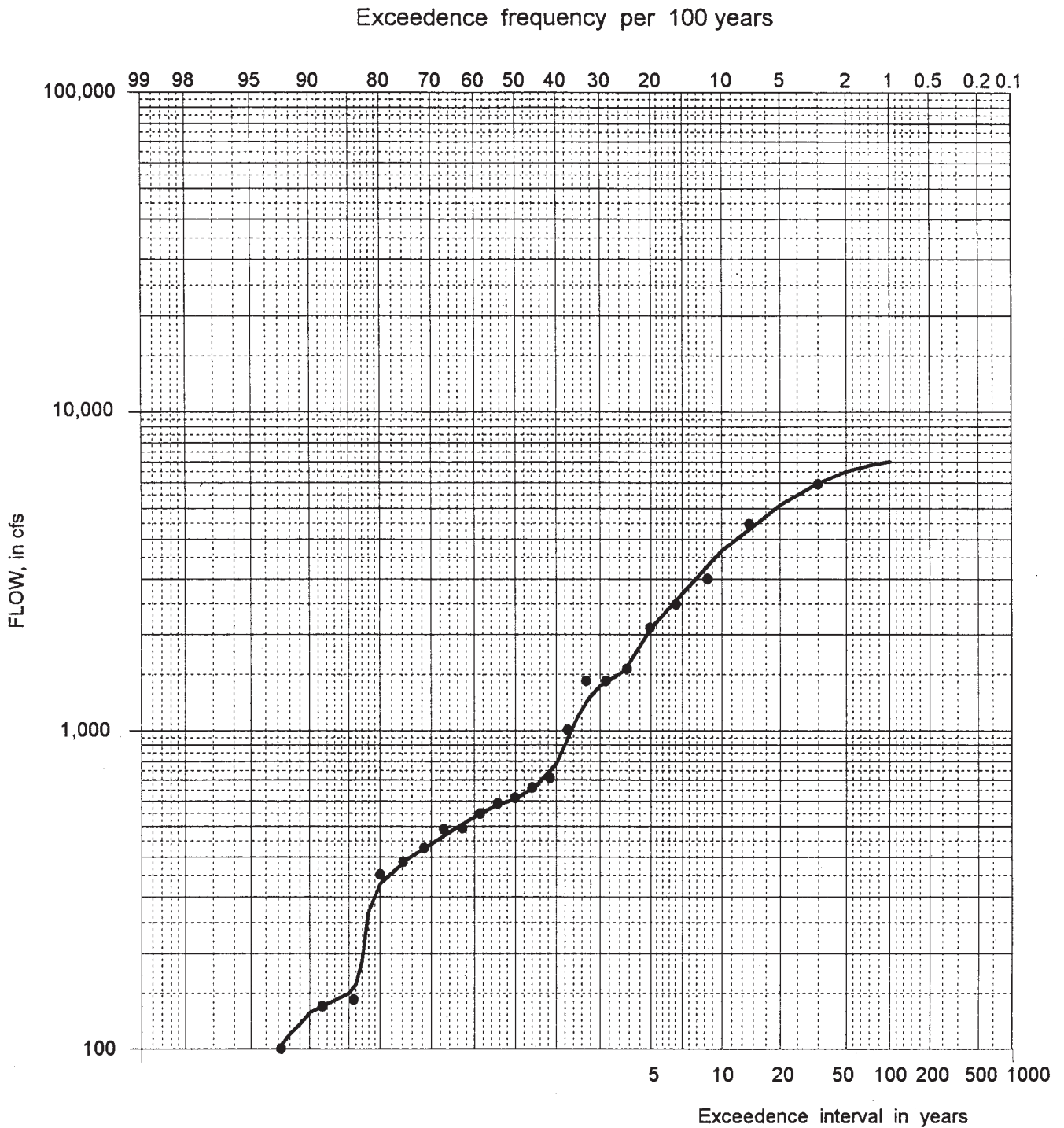
**PEAK RAIN FLOOD FREQUENCY CURVE
REGULATED CONDITION
FRESNO RIVER BELOW HIDDEN DAM**

**U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT**

Prepared by JTH

Nov 98

PLATE 20



NOTES:

1. Median Plotting Positions
2. Drainage Area: 235 sq. mi.
3. 23 years of record (1976 to 1998)

SACRAMENTO-SAN JOAQUIN BASIN COMPREHENSIVE STUDY

SAN JOAQUIN RIVER BASIN, CALIFORNIA

**PEAK RAIN FLOOD FREQUENCY CURVE
REGULATED CONDITION
CHOWCHILLA RIVER BELOW BUCHANAN DAM**

U.S. ARMY CORPS OF ENGINEERS

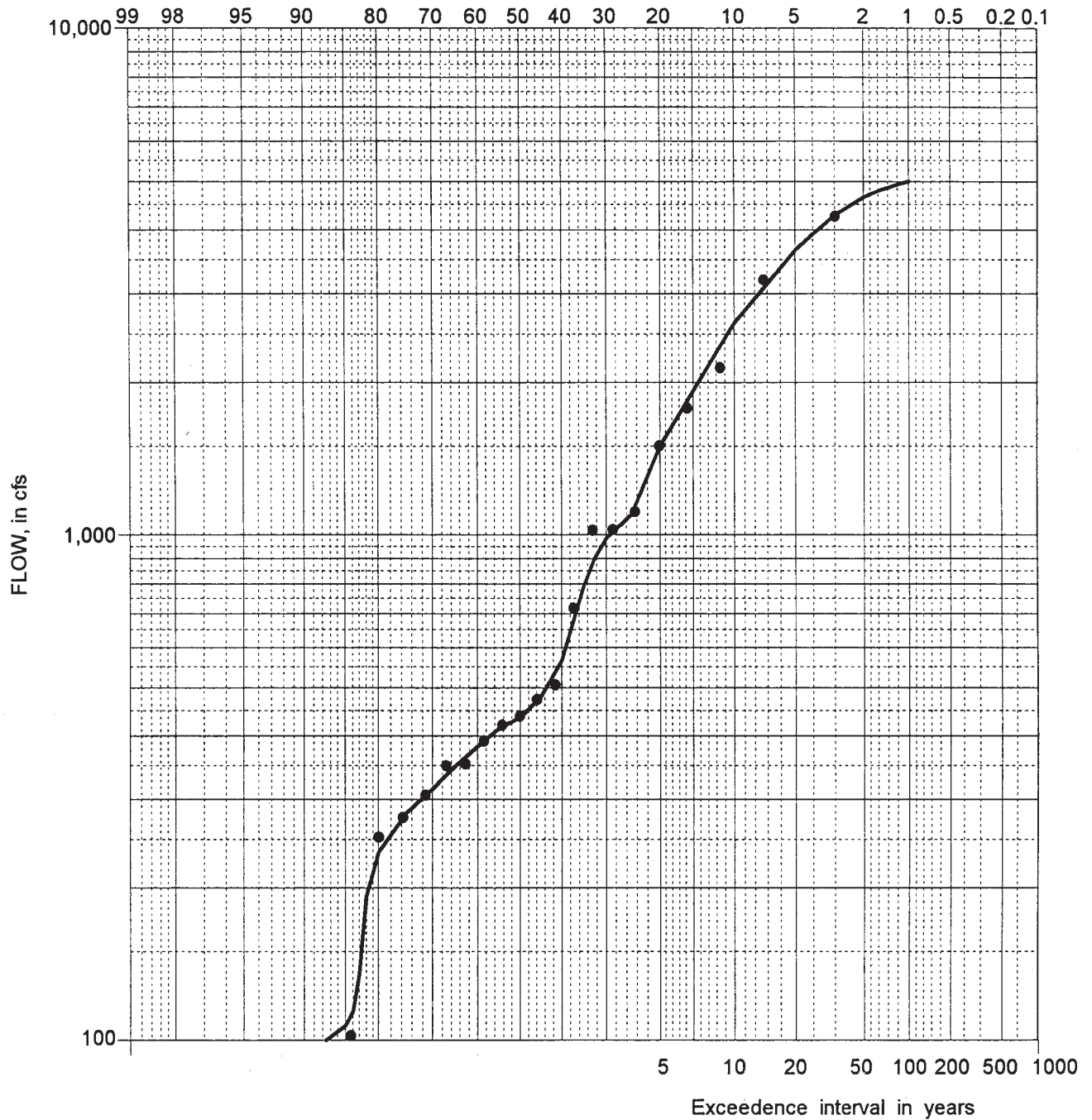
SACRAMENTO DISTRICT

Prepared by JTH

Nov 98

PLATE 21

Exceedence frequency per 100 years



NOTES:

1. Median Plotting Positions
2. Drainage Area: 268 sq. mi.
3. 23 years of record (1976 to 1998)
4. Ash Slough is assumed to transport 71 percent of Chowchilla River peak flows.

SACRAMENTO-SAN JOAQUIN BASIN COMPREHENSIVE STUDY

SAN JOAQUIN RIVER BASIN, CALIFORNIA

**PEAK RAIN FLOOD FREQUENCY CURVE
REGULATED CONDITION
ASH SLOUGH
BELOW CHOWCHILLA RIVER**

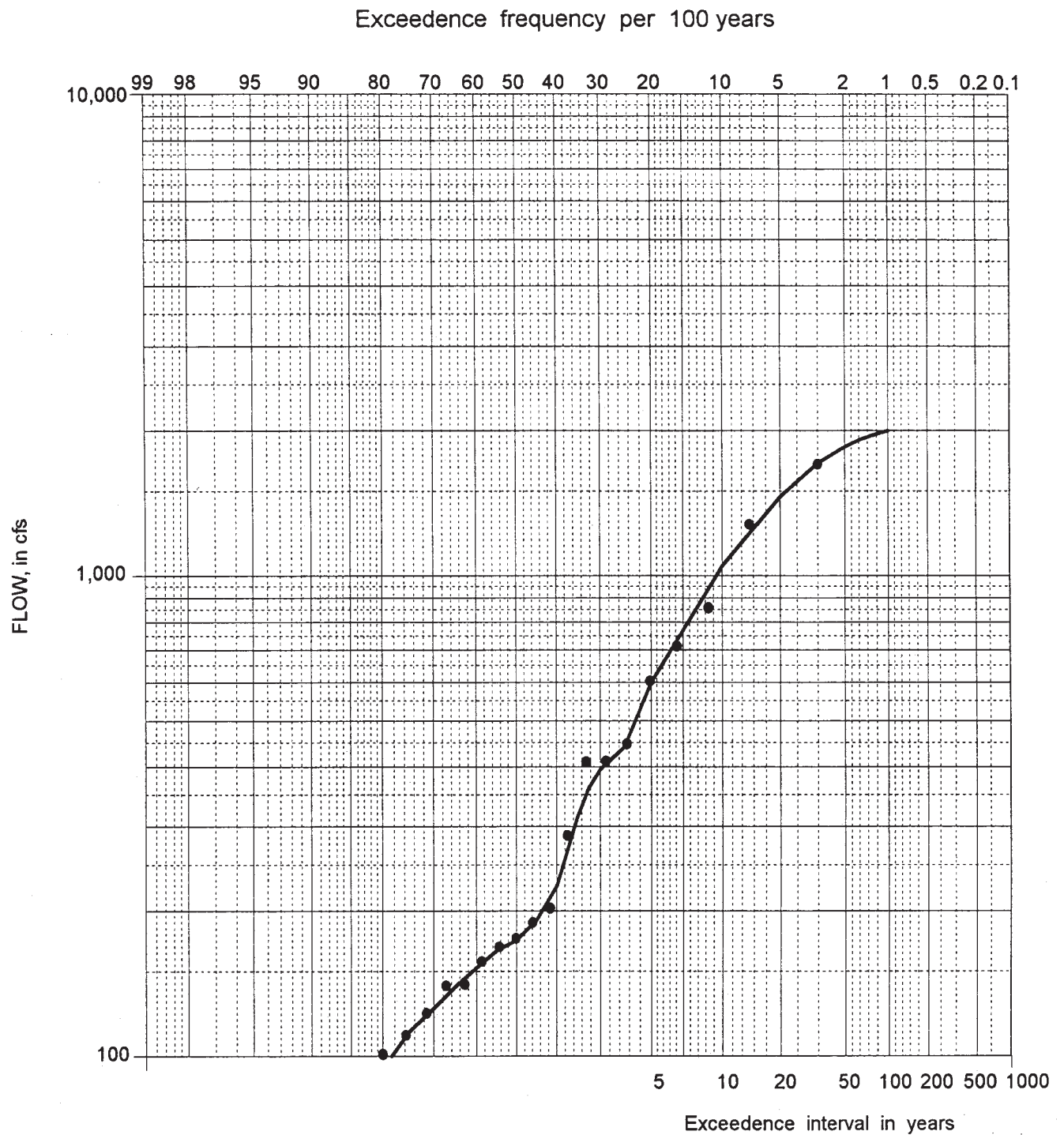
U.S. ARMY CORPS OF ENGINEERS

SACRAMENTO DISTRICT

Prepared by JTH

NOV 98

PLATE 22



NOTES:

1. Median Plotting Positions
2. Drainage Area: 268 sq. mi.
3. 23 years of record (1976 to 1998)
4. Berenda Slough is assumed to transport 29 percent of Chowchilla River peak flows.

SACRAMENTO-SAN JOAQUIN BASIN COMPREHENSIVE STUDY

SAN JOAQUIN RIVER BASIN, CALIFORNIA

**PEAK RAIN FLOOD FREQUENCY CURVE
REGULATED CONDITION
BERENDA SLOUGH
BELOW CHOWCHILLA RIVER**

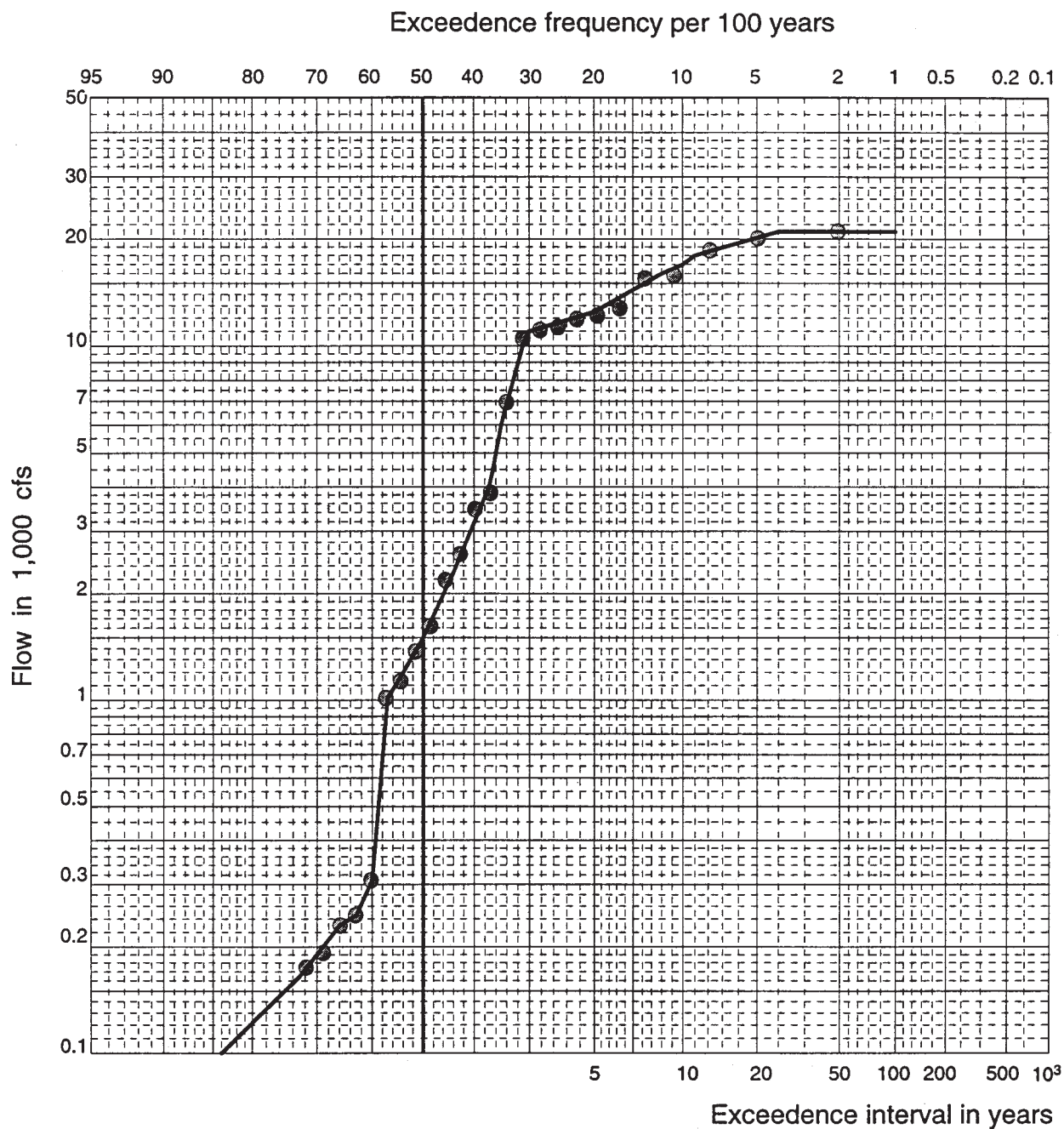
U.S. ARMY CORPS OF ENGINEERS

SACRAMENTO DISTRICT

Prepared by JTH

Nov 98

PLATE 23



NOTES:

1. Drainage Area is 5,630 sq. mi.
2. Median plotting positions based on 34 years of record (1965-1998).
3. Curve is graphically drawn.
4. Flows before 1976 are simulated.
5. Does not include flow in San Joaquin River.

**SACRAMENTO-SAN JOAQUIN BASIN COMPREHENSIVE STUDY
SAN JOAQUIN RIVER BASIN, CALIFORNIA**

**1-DAY RAIN FLOOD FLOW FREQUENCY CURVE
REGULATED CONDITION
EASTSIDE BYPASS NR EL NIDO**

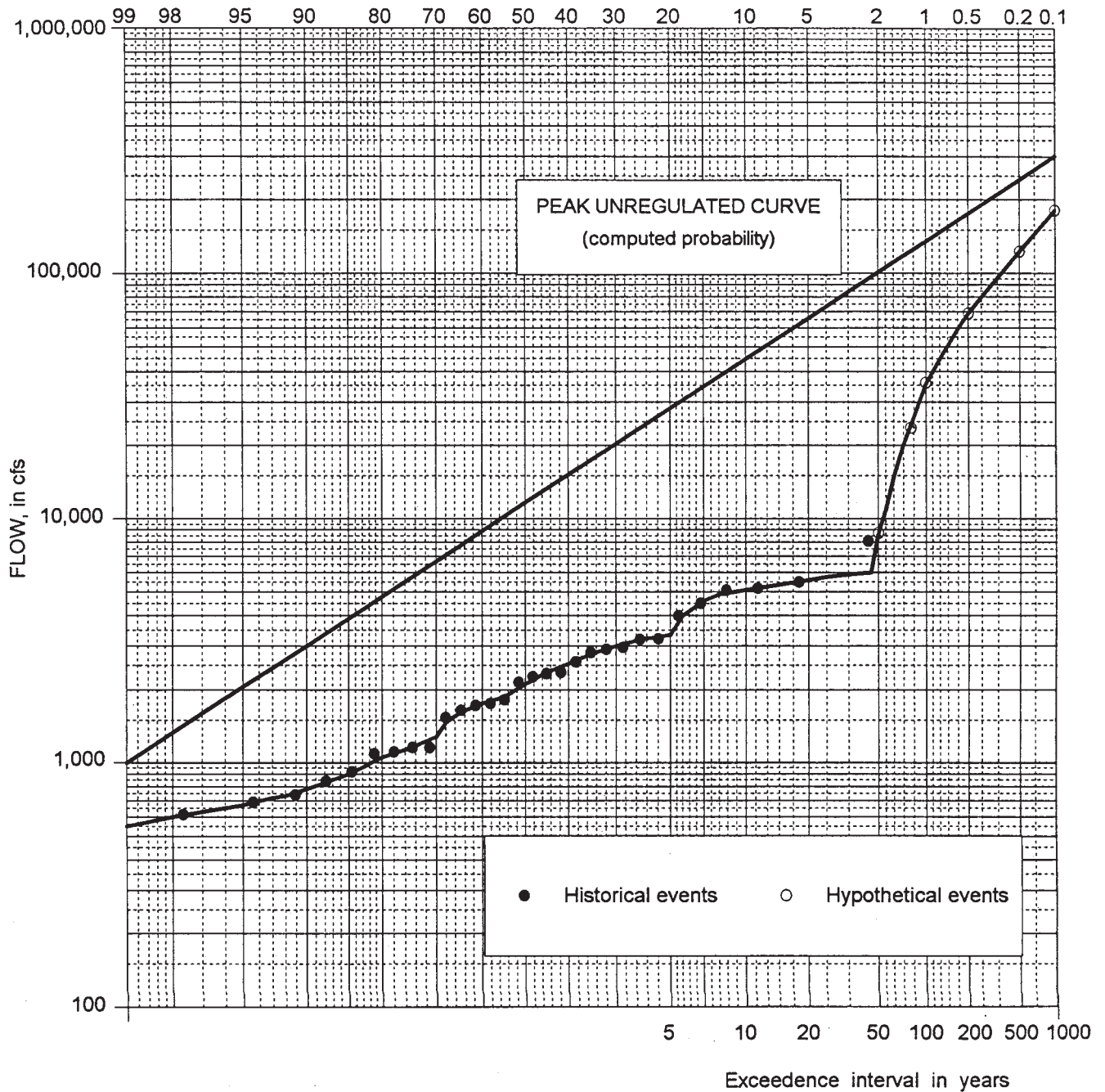
**U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT**

Prepared by JAL

Dec 98

PLATE 24

Exceedence frequency per 100 years



NOTES:

1. Median Plotting Positions
2. Drainage Area: 1,037 sq. mi.
3. 30 years of record (1968 to 1997)

SACRAMENTO-SAN JOAQUIN BASIN COMPREHENSIVE STUDY

SAN JOAQUIN RIVER BASIN, CALIFORNIA

PEAK RAIN FLOOD FREQUENCY CURVE
REGULATED CONDITION

MERCED RIVER AT NEW EXCHEQUER DAM

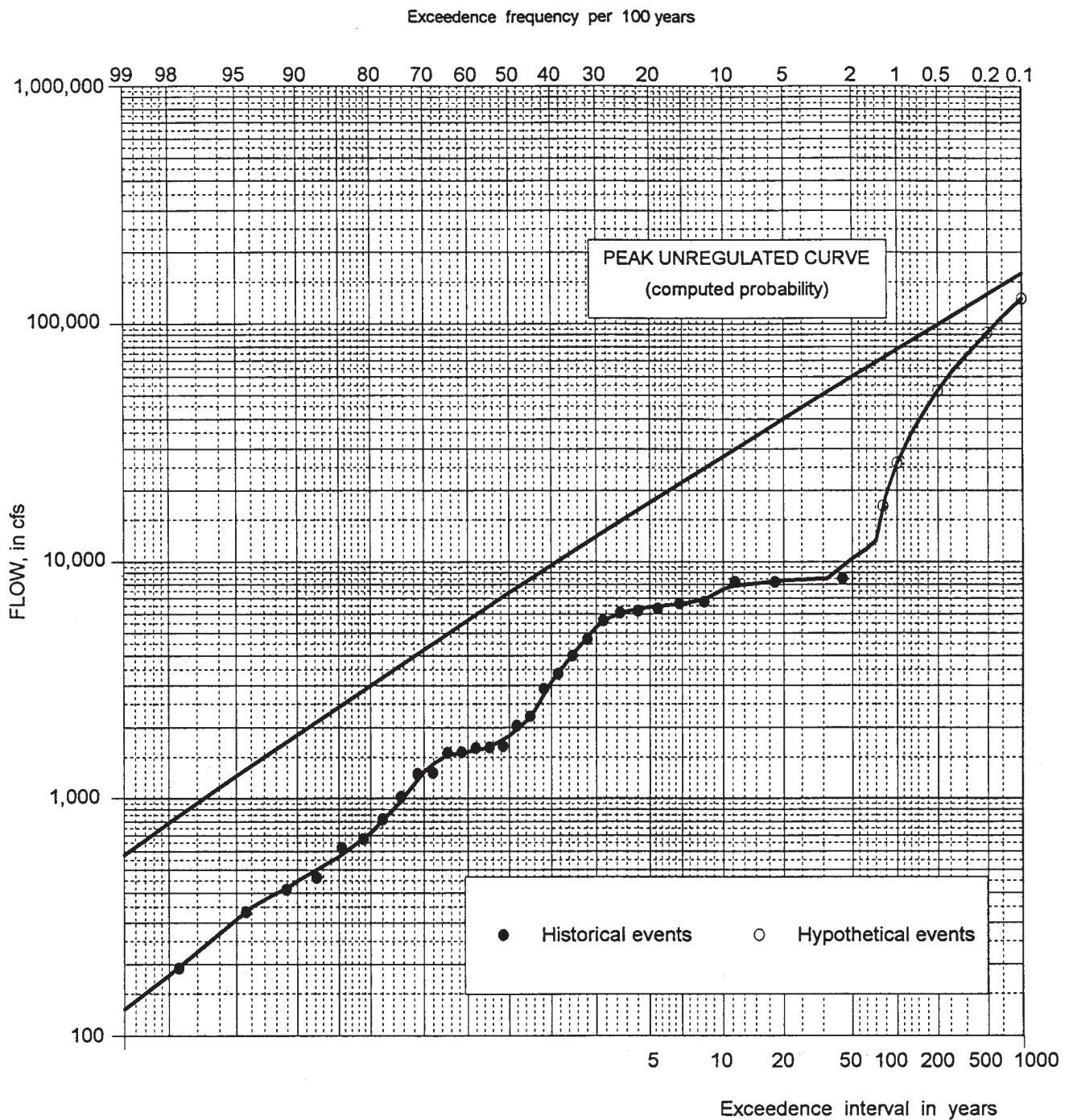
U.S. ARMY CORPS OF ENGINEERS

SACRAMENTO DISTRICT

Prepared by JTH

Nov 98

PLATE 25



NOTES:

1. Median Plotting Positions
2. Drainage Area: 1,224 sq. mi.
3. 30 years of record (1968 to 1997)

SACRAMENTO-SAN JOAQUIN BASIN COMPREHENSIVE STUDY

SAN JOAQUIN RIVER BASIN, CALIFORNIA

**PEAK RAIN FLOOD FREQUENCY CURVE
REGULATED CONDITION**

MERCED RIVER AT CRESSEY

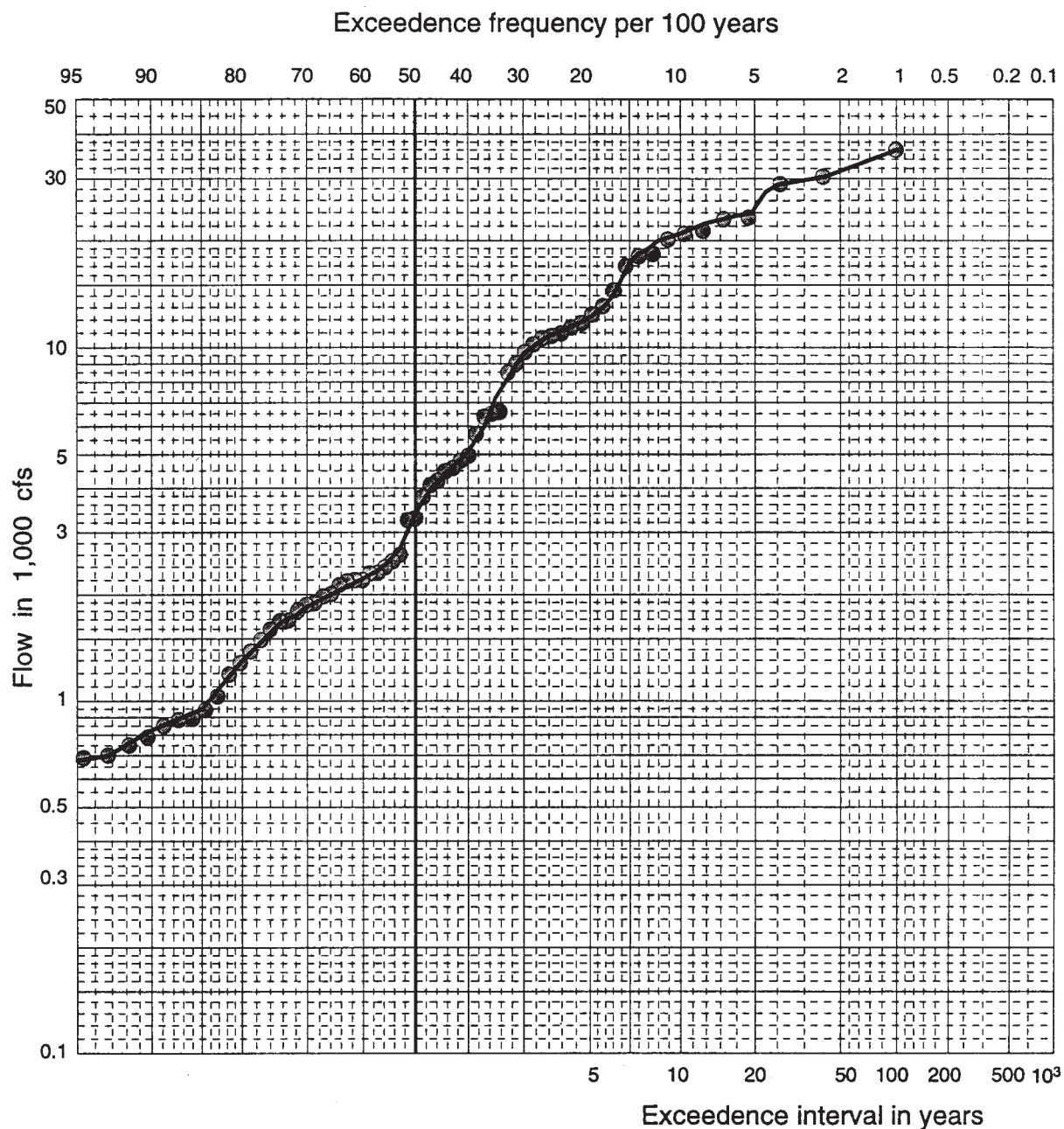
U.S. ARMY CORPS OF ENGINEERS

SACRAMENTO DISTRICT

Prepared by JTH

Nov 98

PLATE 26



NOTES:

1. Drainage area is 9,520 sq. mi.
2. Median plotting positions based on 69 years of record (1930-1998)
3. Curve is graphically drawn.
4. Flows before 1975 are simulated.
5. Flows considered at latitude and may include flow out of channel.

**SACRAMENTO-SAN JOAQUIN BASIN COMPREHENSIVE STUDY
SAN JOAQUIN RIVER BASIN, CALIFORNIA**

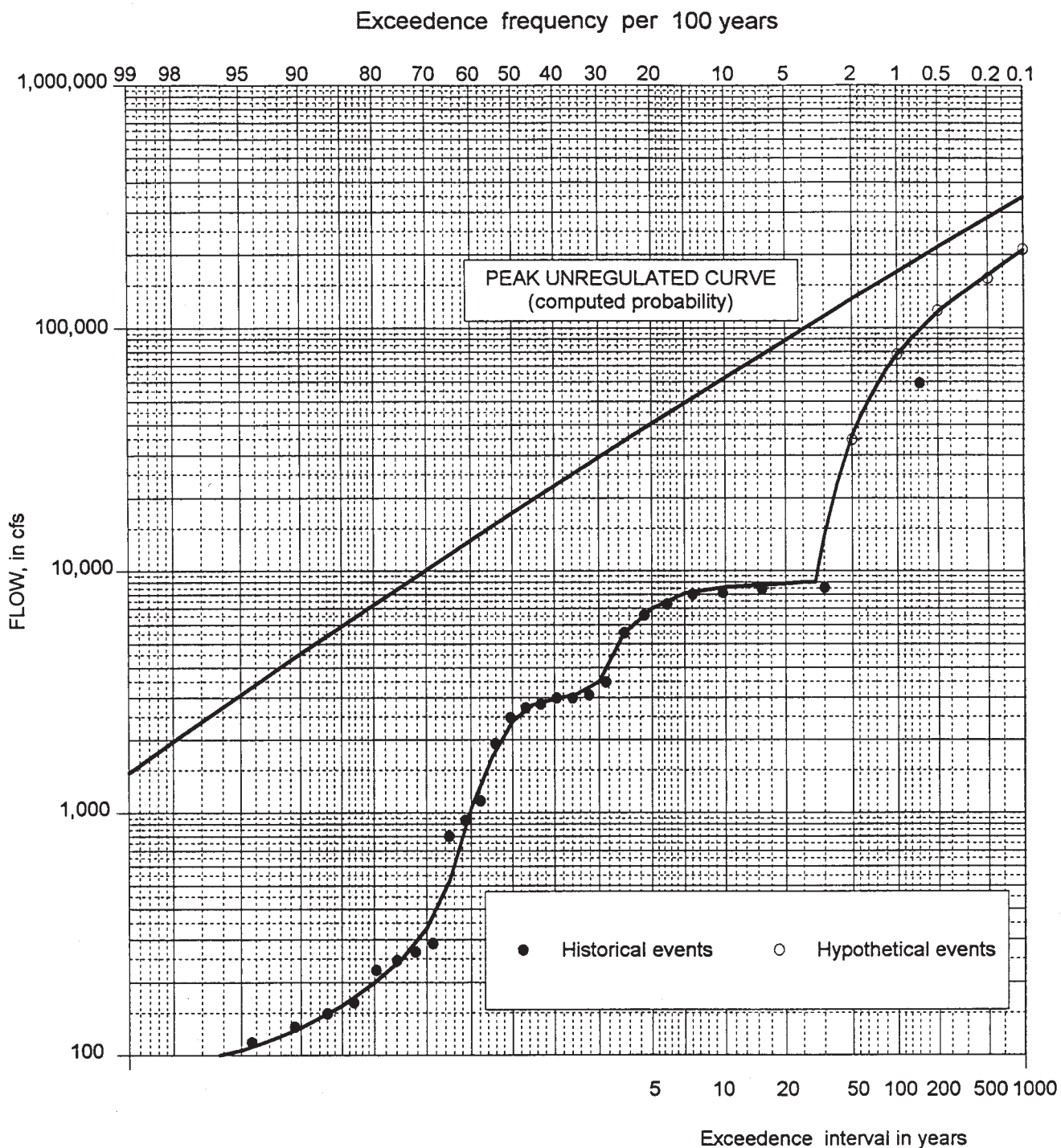
**1-DAY RAIN FLOOD FLOW FREQUENCY CURVE
REGULATED CONDITION
SAN JOAQUIN RIVER NEAR NEWMAN**

**U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT**

Prepared by JAL

Dec 98

PLATE 27



NOTES:

1. Median Plotting Positions
2. Drainage Area: 1,533 sq. mi.
3. 27 years of record (1971 to 1997)
4. 1997 plots as maximum in 101 years

SACRAMENTO-SAN JOAQUIN BASIN COMPREHENSIVE STUDY

SAN JOAQUIN RIVER BASIN, CALIFORNIA

**PEAK RAIN FLOOD FREQUENCY CURVE
REGULATED CONDITION**

TUOLUMNE RIVER AT DON PEDRO DAM

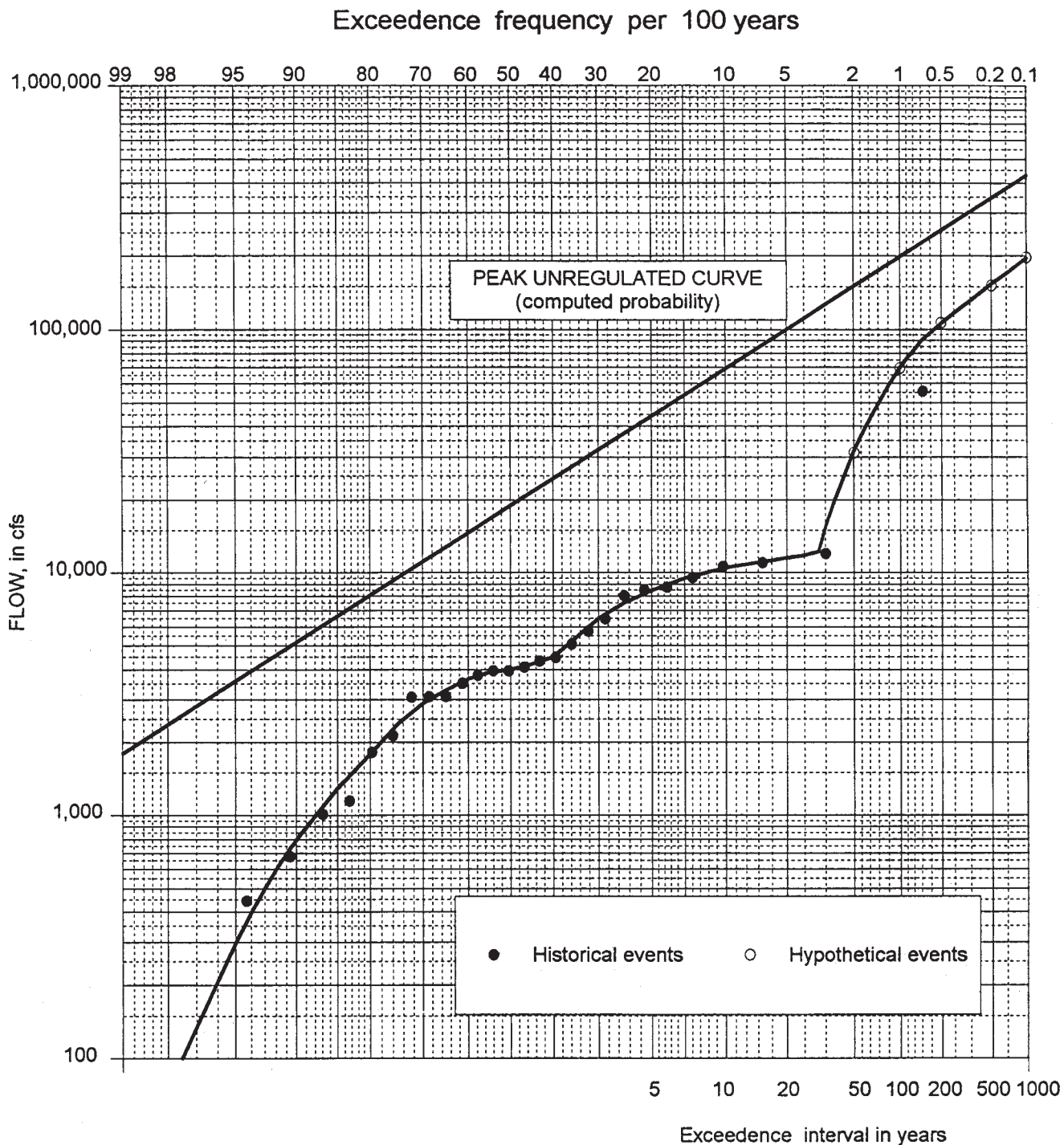
U.S. ARMY CORPS OF ENGINEERS

SACRAMENTO DISTRICT

Prepared by TKP

Nov 98

PLATE 28



NOTES:

1. Median Plotting Positions
2. Drainage Area: 1,884 sq. mi.
3. 27 years of record (1971 to 1997)
4. 1997 plots as maximum in 101 years

SACRAMENTO-SAN JOAQUIN BASIN COMPREHENSIVE STUDY

SAN JOAQUIN RIVER BASIN, CALIFORNIA

**PEAK RAIN FLOOD FREQUENCY CURVE
REGULATED CONDITION**

TUOLUMNE RIVER AT MODESTO

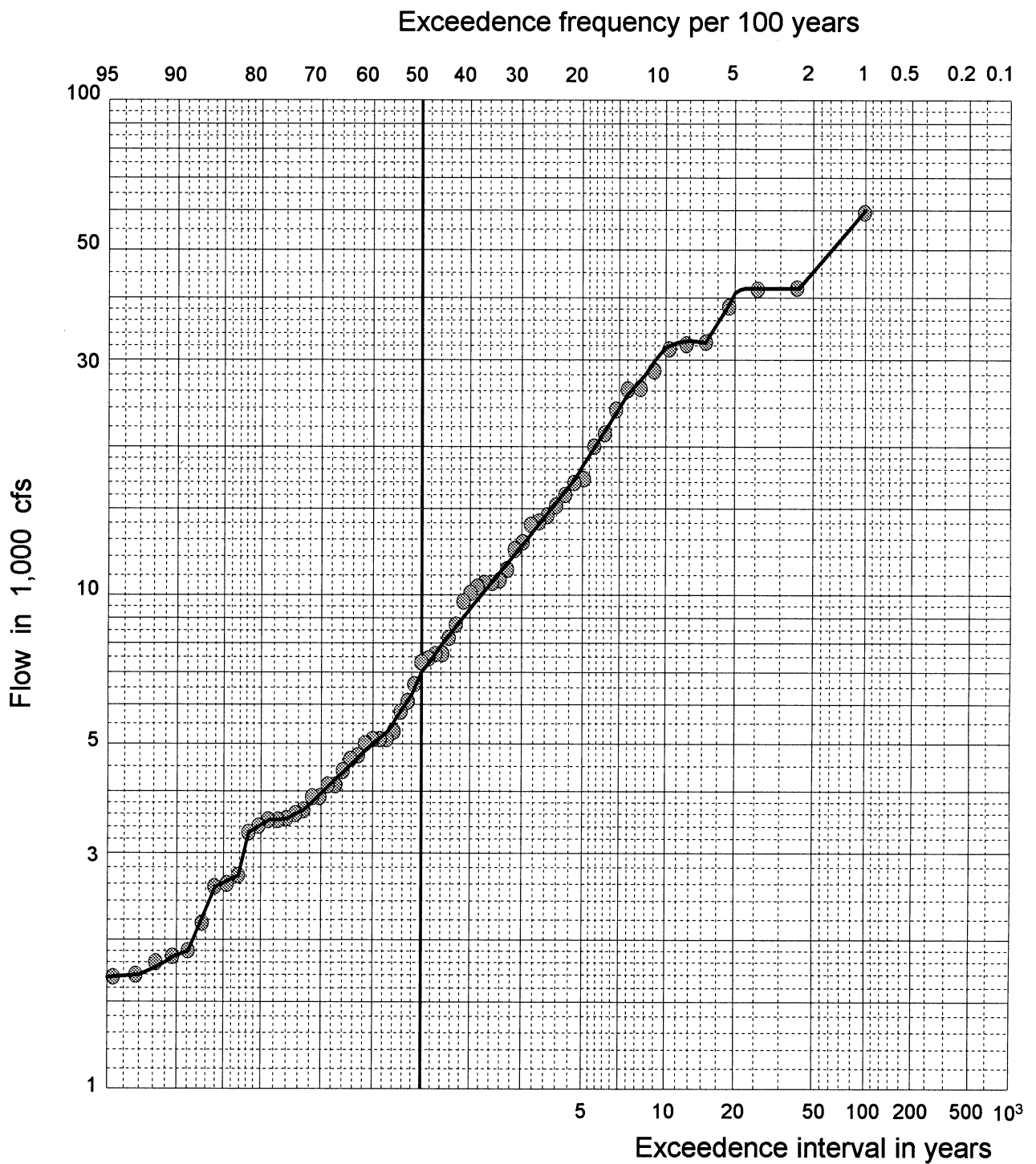
U.S. ARMY CORPS OF ENGINEERS

SACRAMENTO DISTRICT

Prepared by TKP

Nov 98

PLATE 29



NOTES:

1. Drainage Area is 12,400 sq. mi.
2. Median plotting positions based on 69 years of record (1930-1998).
3. Curve is graphically drawn.
4. Flows before 1976 are simulated.
5. Flows considered at latitude and may include flow out of channel.

SACRAMENTO-SAN JOAQUIN BASIN COMPREHENSIVE STUDY
SAN JOAQUIN RIVER BASIN, CALIFORNIA

1-DAY RAIN FLOOD FREQUENCY CURVE
REGULATED CONDITION
SAN JOAQUIN RIVER NEAR MAZE ROAD BRIDGE

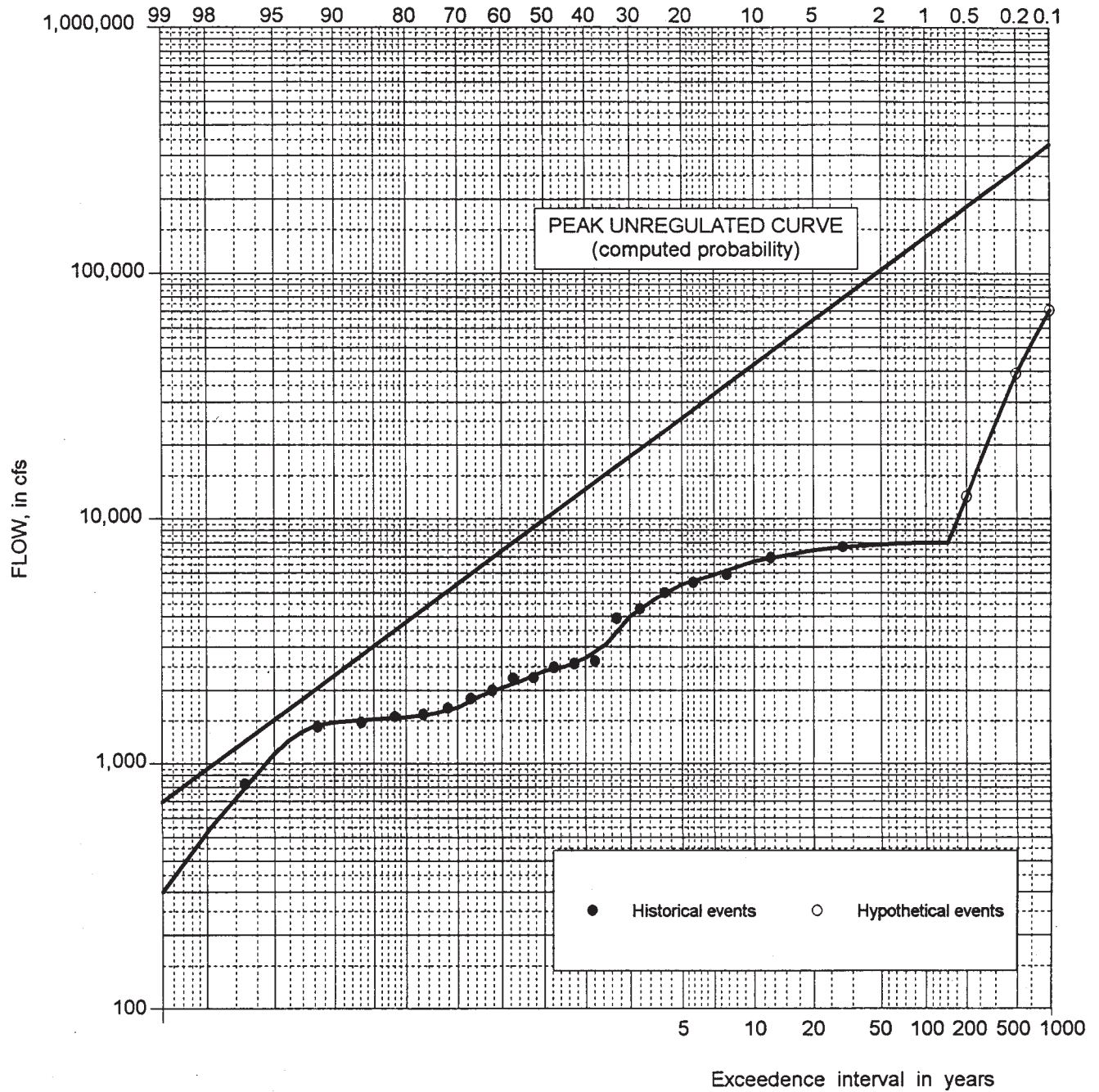
U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by JAL

Dec 98

PLATE 30

Exceedence frequency per 100 years



NOTES:

1. Median Plotting Positions
2. Drainage Area: 905 sq. mi.
3. 20 years of record (1978 to 1997)

SACRAMENTO-SAN JOAQUIN BASIN COMPREHENSIVE STUDY

SAN JOAQUIN RIVER BASIN, CALIFORNIA

PEAK RAIN FLOOD FREQUENCY CURVE
REGULATED CONDITION

STANISLAUS RIVER AT NEW MELONES DAM

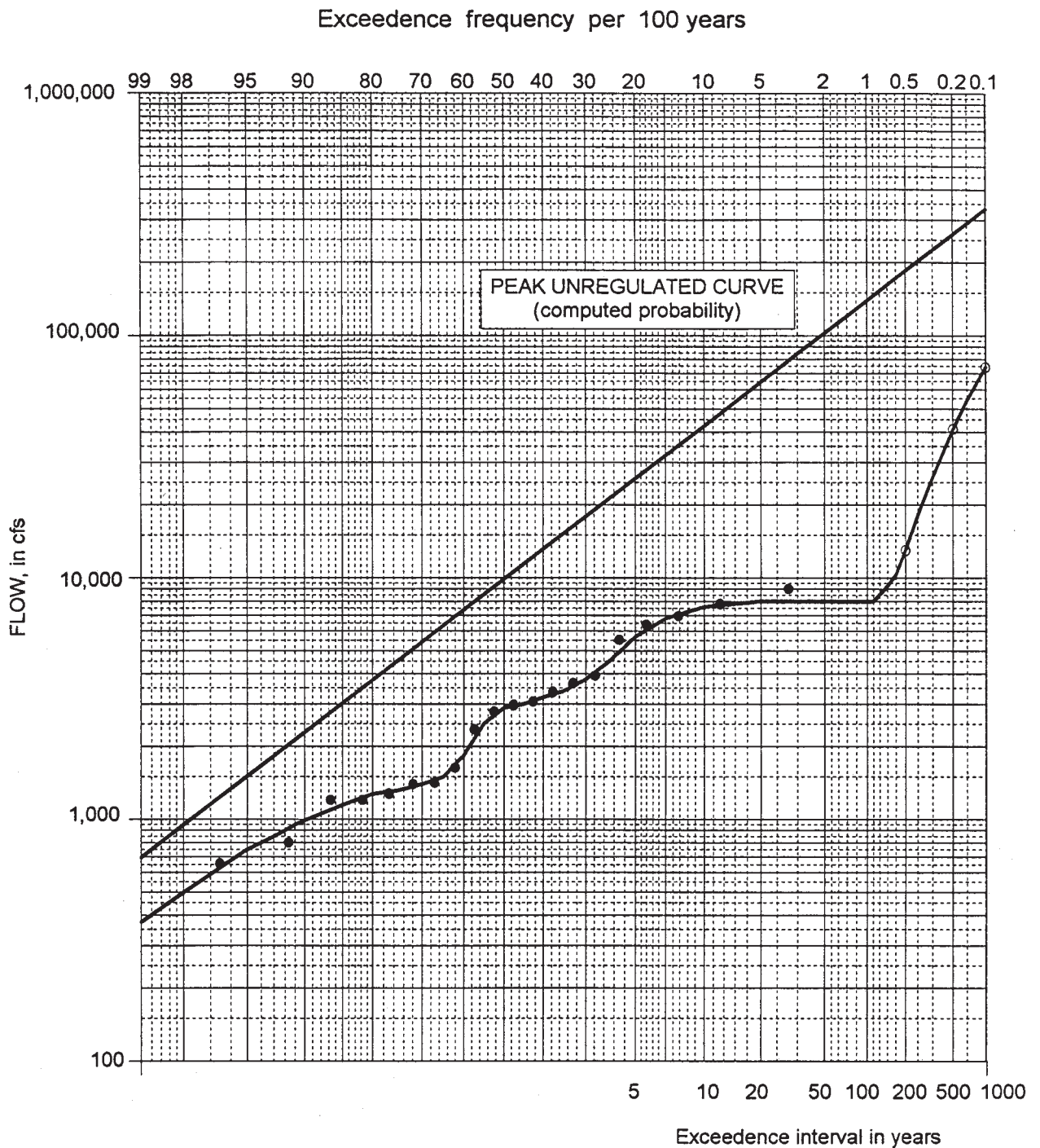
U.S. ARMY CORPS OF ENGINEERS

SACRAMENTO DISTRICT

Prepared by TKP

Nov 98

PLATE 31



NOTES:

1. Median Plotting Positions
2. Drainage Area: 1,020 sq. mi.
3. 20 years of record (1978 to 1997)

SACRAMENTO-SAN JOAQUIN BASIN COMPREHENSIVE STUDY

SAN JOAQUIN RIVER BASIN, CALIFORNIA

**PEAK RAIN FLOOD FREQUENCY CURVE
REGULATED CONDITION**

STANISLAUS RIVER AT ORANGE BLOSSOM BRIDGE

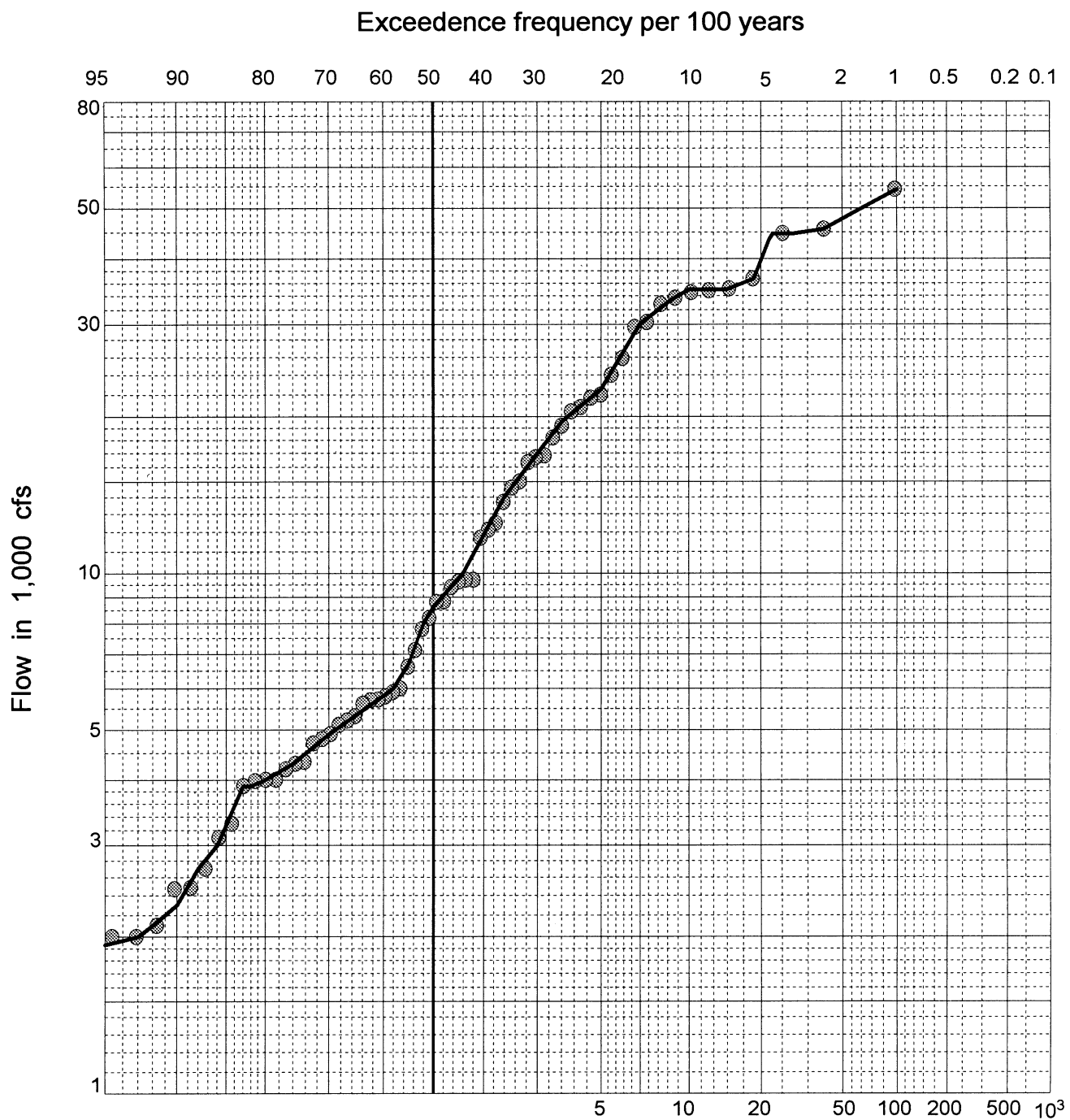
U.S. ARMY CORPS OF ENGINEERS

SACRAMENTO DISTRICT

Prepared by TKP

Nov 98

PLATE 32



NOTES:

1. Drainage area is 13,536 sq. mi.
2. Median plotting positions based on 69 years of record (1930-1998).
3. Curve is graphically drawn.
4. Flows before 1979 are simulated.
5. Flows considered at latitude and may include flow out of channel.
6. 1997 data point is based on USGS estimate of daily maximum in-channel flow and plots as highest flow of record (54,300 cfs).

Prepared by JAL

**SACRAMENTO-SAN JOAQUIN BASIN COMPREHENSIVE STUDY
SAN JOAQUIN RIVER BASIN, CALIFORNIA**

**1-DAY RAIN FLOOD FREQUENCY CURVE
REGULATED CONDITION
SAN JOAQUIN RIVER NEAR VERNALIS**

**U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT**